Impact Evaluation of 2011 Prescriptive Gas Measures

Final Report

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1. Executive Summary

This report presents the results of the impact evaluation of the Program Year 2011 (PY2011) Massachusetts Prescriptive Gas Measures Program. The evaluation consists of on-site monitoring and verification of the savings for a sample of participants for four of the top five measures installed, in terms of savings. The sample sites were monitored for about eight weeks in an attempt to capture seasonally sensitive variations in energy consumption between the winter and swing seasons. The first monitoring equipment was installed in the first week of December 2012 and recovery was completed during the second week of March 2013. The on-site sample design was designed to achieve a relative precision of ± 20% at the 80% confidence interval using a two-tail test for the overall program savings.

1.1 Program Savings Results

Table ES 1 provides the on-site savings results, relative performance[1] and relative precision for each of the four prescriptive gas measures that were evaluated as well as the overall total. The overall relative performance for the four measures was about 102% and the relative precision was about ±15.6%. The condensing furnace and condensing boiler measures both had relative performance greater than 100%, at about 160% and 107 % respectively. Since they represent about 85% of total program savings their performance offset the lower relative performance observed for the other two measures. Indirect water heater and infrared heating measures had lower relative performance of 79% and 20% respectively

Table ES 1: Program Savings Results

Description	Revised Tracking Savings (Therms)	On-site Total Savings (Therms)	Relative Performance	Relative Precision
Condensing Boiler	494,087	530,543	107.4%	±18.2%
Condensing Furnace	36,720	58,696	159.8%	±43.8%
Infrared Heating	46,425	9,105	19.6%	±27.7%
Indirect Water Heater	44,505	34,948	78.5%	±16.2%
Total	621,737	633,293	101.9%	±15.6%

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[1] Relative performance is defined as the ratio of on-site savings divided by the revised tracking savings.

1.2 Measure Savings Recommendations

This section provides the recommended new TRM measure savings values that should be used for tracking and planning purposes.

1.2.1 Condensing Boiler Recommendations

The savings for the condensing boiler measures is derived from three primary variables, the input capacity of the boiler, the measured efficiency of the boiler, and the operating hours - expressed as Equivalent Full Load Hours (EFLH). The capacity values were addressed as part of the 2011 KEMA evaluation of condensing boilers and the current savings recommendation includes these values. The mean measured efficiency observed in the PY 2010 evaluation sample (2012 study)[2] was 88.9%, and the mean measured efficiency for the PY 2011 evaluation sample (2013 study) is 89.5%. The recommended efficiency value of 89.2% is calculated by pooling the values from the two studies based upon the error bounds.

The mean EFLH observed in the PY 2010 sample was 1,421 hours per year, and the mean EFLH observed in PY 2011 is 1,412 hours. There was some variation observed within the size categories, but most category level samples were small and there is no compelling reason to develop different EFLH values for the different categories. As a result, it is recommended that the EFLH value for the recommended savings calculation be changed to 1,416 hours for all size categories, which was calculated by pooling the values from the two studies.

Table ES 2 provides the savings variables and the recommended savings values (shown in bold font), which should be incorporated into the TRM and used as measure savings values in the PA tracking systems. These recommended updates represent about a 3% increase in savings, which is a conservative adjustment given the evaluated relative performance of 107% for this measure. The recommended savings values from the Massachusetts Technical Reference Manual for Program Year 2011 – Report Version, August 2012 (Report 2011) shown in the last column for comparison.

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Table ES 2: Recommended Condensing Boiler Savings[3]

Size Category	Capacity (MBtu)	Efficiency	EFLH	Recommended Savings (ΔMMBtu/Unit/yr)	PY 2011 MA TRM Report Savings (ΔMMBtu/Unit/yr)
Capacity ≤ 300 95% AFUE	150	92.1%	1416	**27.8**	NA
Capacity ≤ 300	209.6	89.2%	1416	**30.6**	29.8
300 < Capacity < 500	400	89.2%	1416	**58.4**	56.9
500 ≤ Capacity < 1000	735	89.2%	1416	**107.3**	104.6
1000 ≤ Capacity ≤ 1700	1350	89.2%	1416	**197.2**	192.1
1700 < Capacity	2363	89.2%	1416	**345.1**	336.2

The savings table also includes a recommended savings value for condensing boilers with an input capacity less than or equal to 300 MBtu and an Average Fuel Utilization Efficiency (AFUE) of 95% or greater. There were 104 of these 95% AFUE condensing boilers certified by the Air-Conditioning, Heating and Refrigeration Institute (AHRI) and the mean input capacity value was 127.5 MBtu. The capacity value of 150 MBtu was selected for the savings calculation because it represented the single most popular size option and was not unreasonably far from the mean. The Program Administrator's (PA's) should monitor the capacity of program participant boilers of this class and adjust this number as data becomes available.[4]

Table ES 3 provides a summary of the condensing boiler savings values through various "Report" versions of the MA TRM, which are defined as follows;

- Report 2010 = savings from the MA TRM 2010 Program Year – Plan Version August 2011
- Report 2011 = savings from the MA TRM 2011 Program Year – Report Version August 2012
- Report 2012 = KEMA recommended savings from this report

[3] Values shown were derived through expanding the site data to the full population. For example, "Capacity" is the average nameplate rating by bin. The capacity value for the 95% AFUE < 300 MBH boiler is smaller due to the size distribution of available boilers.

[4] The mean capacity value of the 104 AHRI certified boilers was 127.5 MBtu, only about 14% of those boilers had an input capacity of 210 MBtu or greater. There were a total of 13 boilers (12.5% of the total) with a capacity rating of 150 MBtu.

Table ES 3: Summary of Condensing Boiler Savings

Size	Efficiency Requirement	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
<= 300 MBH	>= 90% AFUE	22.1	29.8	**30.6**
301-499 MBH	>=90% Thermal Efficiency	42.3	56.9	**58.4**
500-999 MBH	>=90% Thermal Efficiency	77.1	104.6	**107.3**
1000-1700 MBH	>=90% Thermal Efficiency	142.6	192.1	**197.2**
1701+ MBH	>=90% Thermal Efficiency	249.0	336.2	**345.1**

1.2.2 Condensing Furnace Recommendations

The condensing furnace savings calculations utilize the same three primary savings variables as the condensing boilers, the input capacity of the furnace, the measured efficiency of the furnace, and the operating hours (expressed as EFLH).

The mean EFLH observed in the PY 2010 evaluation sample was 452 hours per year and the EFLH for the PY 2011 evaluation sample was 409 hours, based upon a sample of 12 and 10 furnaces respectively. Initially it was postulated that the warm temperatures during the 2012 study may have biased the results producing lower than expected operating hours, however the temperatures during the 2013 study were more normal and the average EFLH were actually reduced. Although secondary research indicated that the mean hours are lower than would typically be expected for commercial use there were several factors that contribute to the low operating hours observed in the sample as follows;

- Low operating hours of the facility or space served by the furnace,
- Furnace heating capacity is oversized for the space served,
- Additional heating sources already serving the space, and
- Use of programmable thermostats with aggressive setback settings.

Table ES 4 provides the recommended savings (Report 2012) for each furnace efficiency category, which represent about a 26% increase from the MA PY 2011 Report TRM savings values. The recommended savings values were developed from the mean savings values of the PY 2010 and PY 2011 sample sites.

Table ES 4: Recommended Condensing Furnace Savings[5]

Furnace Efficiency	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
Furnace AFUE =>92%	21.1	5.9	**7.5**
Furnace AFUE =>92% w/ECM	19.6	5.5	**6.9**
Furnace AFUE =>94% w/ECM	23.6	6.2	**8.5**
Furnace AFUE =>95% w/ECM	NA	NA	**9.0**
Furnace AFUE =>96% w/ECM	NA	NA	**9.5**
Furnace AFUE =>97% w/ECM	NA	NA	**9.9**

Savings values were also calculated for three new condensing furnace efficiency categories as shown at the bottom of the table. These savings were calculated assuming that the mean input capacity for each would be 100 MBtu and that the EFLH would be 440 hours.[6]

1.2.3 Infrared Heater Recommendations

The Infrared Heater (IR Heater) savings calculation is somewhat similar to the previous heating measures except that the radiant nature of an IR Heater allows the unit to be sized smaller than a conventional warm air heater. The primary variable that impacts the IR Heater savings calculation is operating hours expressed as EFLH. The mean EFLH observed in the PY 2010 sample was 677 hours, which was significantly higher than the EFLH of 302 hours observed for the PY 2011 sample. The PY 2011 sample included buildings that were primarily using the IR heaters to keep products from freezing and set point temperatures were extremely low. The PY 2010 sample also had buildings with similar heating applications, but it also contained buildings that used the heaters for space heating and the hours for those units were significantly higher than the mean. This technology has the potential to achieve significantly higher savings than has been observed in the PY 2011 sample, however implementing the measure through a prescriptive program has resulted in projects that only achieve marginal savings.

This measure has been evaluated for two years and all of the project savings have been significantly lower than the Report 2010 savings value of 74.4 MMBtu/unit. The Report 2011 savings of 22.3 MMBtu/unit is equal to the mean savings value from the KEMA Prescriptive Gas Final Program Evaluation Report,

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[5] The savings values for the 95%, 96% and 97% AFUE furnaces were not included in the 2010 and 2011 Report versions of the MA TRM.

[6] The mean capacity for each of the higher efficiency categories was 80 to 86 MBtu so a mean program participant capacity value of 100 MBtu seems reasonable. Again the PA's could monitor this variable and make adjustments to the TRM as necessary.

June 2012, which evaluated Program Year 2010 measures. The mean savings value from this year's study of PY 2011 measures was significantly lower at 7.2 MMBtu/unit. The two-year mean savings of 12.0 MMBtu/unit is the recommended savings for this measure as shown in last column of Table ES 5.

Table ES 5: Recommended Infrared Heater Savings

Measure Type	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
Infrared Heater	74.4	22.3	**12.0**

1.2.4 Indirect Water Heater Recommendations

The Indirect water heater savings is primarily a function of the amount of domestic hot water usage and as such, it is difficult to develop a prescriptive variable that would be predictive with respect to the amount of savings. The mean annual savings value observed in the PY 2010 on-site sample was 20.7 MMBtu/unit, and the mean annual savings value observed in the PY2011 on-site sample was 17.2 MMBtu/unit. In both samples, there are large variations in the savings due to the water usage even though the mean savings for both samples was lower than the original savings of 30.4 MMBtu there were five sample sites that had savings that exceeded the original savings estimate (3 in PY 2010 and 2 in PY 2011). The recommended annual savings value was calculated using the simple average of savings results from the two studies and is 19.0 MMBtu/unit as shown in Table ES 6.

Table ES 6: Recommended Indirect Water Heater Savings

Measure Type	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
Indirect Water Heater	30.4	20.7	**19.0**

2. Introduction

This report presents the results of the impact evaluation of the Program Year 2011 (PY2011) Massachusetts Prescriptive Gas Measures Program. The evaluation consists of on-site monitoring and verification of the savings for a sample of participants for four of the top five measures installed, in terms of savings. The sample sites were monitored for about eight weeks in an attempt to capture seasonally sensitive variations in energy consumption between the winter and swing seasons. The first monitoring equipment was installed in early December 2012 and recovery was completed during the second week of March 2013. The on-site sample design was designed to achieve a relative precision of ± 20% at the 80% confidence interval using a two-tail test for the overall program savings.

Evaluation activities included on-site monitoring and verification of the savings, surveys, secondary research and a review of billing data for a sample of participants in the 2011 program year. The design of this evaluation, the third annual review of the Prescriptive gas program, built on the insights of the first two. Some of the highlights of this effort include:

- Site-level sample design that focuses on measures that can be monitored using proxy variables to capture operating characteristics. Four of the top seven measures in terms of total program savings were selected for onsite verification; condensing boilers and furnaces, indirect water heaters, and infrared heaters.
- Spray valves and programmable thermostats are two of the other measures in the top seven. A separate study to collect pre- and post-project water usage data will be proposed for spray valves, which is outside the scope of this evaluation. Opportunistic data collection was originally planned to be used to measure the savings from programmable thermostats. The protocol for all HVAC measure site visits included collection control mechanism data, including the set points and schedules of programmable thermostats.
- An engineering literature review of programmable thermostat studies was performed and compared to the results of this review and to TRM savings values.
- Onsite metering at heating sites was scheduled for ten to twelve weeks to include monitoring during both winter and swing-season periods for seasonally sensitive measures.
- Measure results are reported as savings recommendations.
- More robust savings estimates for the four target measures of the previous evaluations (condensing boilers and furnaces, indirect water heaters, and infrared heaters) were developed through analysis that integrated multi-year results.

2.1 Purpose of Study

The primary objective of the PY2011 Prescriptive Gas Evaluation was to complete a retrospective impact evaluation for the selected measures through site inspection, monitoring and analysis. The evaluation was based on the population of measures rebated during the 2011 program year and selected measures were sampled at the site-level. The goal of this gas evaluation was to develop measure level savings values for program planning and for reporting 2012 and possibly later program results. The evaluation was targeted to produce findings at the 80% confidence level with precision of plus or minus 20% for the full prescriptive gas program. Confidence and precision at the individual measure level were also calculated and presented.

2.2 Scope

The scope of work for this evaluation project was to develop statewide recommendations for prescriptive measure savings values for condensing boilers, condensing furnaces, infrared heaters and indirect water heaters. There was no attempt to develop PA-level recommendations regarding the reporting of overall Prescriptive Gas Program results statewide. On-site monitoring was conducted for a sample of the following measures;

- Condensing Boilers,
- Condensing Furnaces,
- Infrared Heaters, and
- Indirect Water Heaters.

The data collected through the monitoring effort was processed, analyzed, and expanded to the population level for each measure.

3. Description of Sampling Strategy

DNV KEMA reviewed the participant populations provided by the Program Administrators (PA), analyzed the distributions of savings by PA, measure type, and project numbers and developed the sample plan for PA review.

3.1 Tracking System Data Summary

The population frame for this impact evaluation is the set of prescriptive gas projects rebated in 2011, as included in the tracking system data provided by the six PAs in Massachusetts. DNV KEMA consolidated the PA records into 3,857 unique projects and measure categories. Table 1 shows the distribution of the consolidated tracking system numbers of projects and annual savings in therms, across PAs and measure categories. The top seven measures in terms of annual therms savings are highlighted in yellow and these measures were further examined based upon their relative contribution to annual and lifetime program savings.

Table 1: Prescriptive Measure Annual Savings Overview PY2011

Measures	BERKSHIRE	COLUMBIA	NEW ENGLAND	NGRID	NSTAR	UNITIL	Grand Total
Prescriptive	**42,518**	**56,949**	**18,609**	**1,267,943**	**345,820**	**16,770**	**1,748,608**
Food Service	**248**	**8,656**	**3,088**	**29,970**	**15,213**	**3,308**	**60,483**
Griddle	248			185			433
Fryer		4,688	2,344	14,064	7,618		28,714
Oven		3,968	744	13,377	7,595	3,308	28,992
Steamer				2,344			2,344
Hot Water	**4,554**	**10,820**	**800**	**732,134**	**47,188**	**1,758**	**797,254**
Aerator				21,488	13,022		34,510
electric spray valve					-		-
Indirect Water Heater	2,736	7,866		34,656	14,288	608	60,154
Shower Head				27,924	5,252		33,176
Spray Valve				607,488		1,008	608,496
Tankless Water heater	568	1,704	800	5,751	1,207		10,030
Condensing Water heater	1,250	1,250		3,000	750	142	6,392
Salon Nozzle				31,827	12,669		44,496
HVAC Controls	**1,925**	**6,364**	**154**	**79,611**	**140,220**	**2,310**	**230,584**
Boiler Reset Control		355		16,330	4,260		20,945
Steam Traps		2,313			107,778		110,091
THERMOSTAT	1,925	3,696	154	63,281	28,182	2,310	99,548
HVAC Equipment	**35,791**	**31,109**	**14,567**	**410,518**	**127,353**	**9,394**	**628,732**
Boilers	365	3,272		21,780	5,946	1,210	32,573
Combined Boiler/water heater		1,476	323	5,658	1,476	6,717	15,650
Condensing Boiler	24,078	23,183	12,520	288,524	98,808	1,467	448,580
Furnaces	6,140	2,286	236	34,740	11,303		54,705
INFRARED	5,208	892	1,488	56,544	8,184		72,316
Unit heater				3,272	1,636		4,908
HVAC Structural				**15,710**	**15,846**		**31,555**
Duct/Pipe Insulation				15,710	15,846		31,555

Table 2 provides the rank, percent of annual savings, cumulative percent and number of projects for each of the seven top measures based on annual savings. The top measure for PY 2011 was a low flow pre-rinse spray valve measure which account for 35% of the annual program savings. This measure was the eighth largest measure in PY 2010 and accounted for just over 1% of the program savings. The large increase in the savings for this measure is primarily due to increased installations by National Grid. The second largest measure was Condensing Boilers, which accounted for 26% of the total program savings. The remaining five measures, accounted for 6% or less of the annual program savings each and the top seven measures accounted for 83% of annual savings.

Table 2: Top Measures Annual Savings Analysis

Measure	Rank	Annual Gross Therm Savings	Percent of Total Savings	Cumulative Percentage	# Projects
Spray Valve	1	608,496	35%	35%	1,262
Condensing Boiler	2	448,580	26%	60%	441
Steam Traps	3	110,091	6%	67%	16
Programable Thermostat	4	99,548	6%	72%	538
Infrared Heater	5	72,316	4%	77%	33
Indirect Water Heater	6	60,154	3%	80%	167
Furnaces	7	54,705	3%	83%	230
Totals		**1,453,890**	**83%**		**2,687**

The Top Measures were then analyzed based upon lifetime savings estimates to determine their relative importance to the program. Table 3 provides the rank, percent of total lifetime savings for the top seven annual savings measures, which shows that on a lifetime savings basis the Steam Traps measures drops from the third largest measure (annual basis) to the 17th largest measure. Since lifetime savings is an important component of program impacts and post installation evaluation of steam trap measures can be problematic the measure was dropped from the on-site evaluation effort.

Table 3: Top Measures Lifetime Savings Analysis

Measure	Rank	Lifetime Gross Therm Savings	Percent of Total Savings	Cumulative Percentage	# Projects
Condensing Boiler	1	11,214,500	50%	50%	441
Spray Valve	2	3,042,480	13%	63%	1,262
Programable Thermostat	3	1,374,255	6%	69%	538
Infrared Heater	4	1,229,372	5%	75%	33
Furnaces	5	984,690	4%	79%	230
Indirect Water Heater	6	902,310	4%	83%	167
Steam Traps	17	110,091	0%	83%	16
Totals		**18,857,698**	**83%**		**2,687**

During planning meetings with the Program Administrators (PAs) and the Non-utility Parties (NUPs), it was decided that the Spray Valve measure should not be included in the current program evaluation. Since under the current timeline it would not be possible to capture the pre-installation operation of the spray valves, another study will be planned that will include metering and measurement of the baseline conditions. Based on the numbers of projects, total savings, and ability to monitor, DNV KEMA recommended and the PA's accepted that the four measure categories highlighted in green be the focus of the 2011 prescriptive gas impact evaluation and data collected through on-site measurement.

Programmable thermostats, the third ranking measure in terms of lifetime savings, were subject to data collection as the opportunity presents during on-site investigation of other measures.

The initial population frame for this evaluation is the 3,857 records defined as unique projects in 22 separate measure categories. The four measure categories chosen for on-site M&V in this study include 870 projects.

3.2 Sample Design

The sample was designed to produce statewide overall relative performance ratios with ±20% precision at 80% confidence for the selected Prescriptive Gas measures.

Table 4 presents the sample designs considered for this study stratified by total therms for the selected measure categories in the Prescriptive Gas program. The analysis looks at the impacts of various sample sizes at a target precision level of ±25%. All calculations are made at an 80% confidence level.

A key determinant of sample sizes and anticipated precisions is the amount of variability that is likely to exist from site to site in the parameter being evaluated. This design was based on reasonably conservative error ratios of 0.7. At these levels, the anticipated relative precisions range from a low of ±8% to a high of ±37%.

Table 4: Preliminary Planning Scenarios

Measure	Scenario	Error Ratio	Confidence	Desired Relative Precision	Required Sample Size	Planned Sample Size	Anticipated Relative Precision
Indirect Water Heater	1	0.7	80%	25%	12	30	14.8%
Indirect Water Heater	2	0.7	80%	25%	12	40	12.4%
Indirect Water Heater	3	0.7	80%	25%	12	50	10.6%
Condensing Boiler	1	0.7	80%	25%	13	70	9.8%
Condensing Boiler	2	0.7	80%	25%	13	85	8.7%
Condensing Boiler	3	0.7	80%	25%	13	100	7.9%
Furnaces	1	0.7	80%	25%	12	60	10.0%
Furnaces	2	0.7	80%	25%	12	65	9.4%
Furnaces	3	0.7	80%	25%	12	70	8.9%
INFRARED	1	0.7	80%	25%	9	5	37.0%
INFRARED	2	0.7	80%	25%	9	15	17.1%
INFRARED	3	0.7	80%	25%	9	25	8.8%

Based on the results of the preliminary planning, many potential sample designs were evaluated in an attempt to achieve the highest possible precision within the approximate number of planned sample sites.

Table 5: Sample Design

Measure	Stratum	Max Gross Therms Savings	Projects	Total Therms Savings	Sample	Inclusion Probabilities
Indirect Water Heater	1	304	49	14,896	4	8%
Indirect Water Heater	2	304	50	15,200	4	8%
Indirect Water Heater	3	608	46	15,808	3	7%
Indirect Water Heater	4	2736	22	19,456	3	14%
Condensing Boiler	1	3978	166	54,145	3	2%
Condensing Boiler	2	1692	118	66,834	3	3%
Condensing Boiler	3	4626	105	137,238	3	3%
Condensing Boiler	4	11408	30	86,986	3	10%
Condensing Boiler	5	12450	21	94,620	2	10%
Furnaces	1	211	83	13,258	4	5%
Furnaces	2	236	66	14,430	4	6%
Furnaces	3	422	58	14,603	3	5%
Furnaces	4	2490	23	19,902	3	13%
INFRARED	1	2232	23	27,528	3	13%
INFRARED	2	3720	5	17,112	3	60%
INFRARED	3	5208	3	14,136	2	67%
INFRARED	4	10416	2	19,344	1	50%

Table 5 presents the sample stratification that provided an efficient allocation of 51 sites across the four main measure categories. In Table 6, anticipated precisions for this design indicate that it offers reasonable precision for the largest measure category, with Boilers at ±27%, and a good overall precision of ±19%.

Table 6: Anticipated Precisions

Measure	Projects	Total Therms Savings	Error Ratio	Confidence Level	Planned Sample Size	Anticipated Relative Precision
Indirect Water Heater	167	65,360	0.7	80%	14	24.0%
Condensing Boiler	440	439,823	0.7	80%	14	27.2%
Furnaces	230	62,193	0.7	80%	14	24.8%
Infrared	33	78,120	0.7	80%	9	26.8%
Total	**870**	**645,496**	**0.7**	**80%**	**51**	**19.1%**

3.3 Revision of Tracking Data

The tracking data provided by the PAs in early 2012 did not have consistent savings values for the measures as would be expected for a prescriptive program. The PAs report that this is due to the timing of the data request combined with the varying levels of complexity between PA tracking databases. As a result of this there were up to four different savings values for the same measure in the data and this was not determined until after the sample design had been selected and the on-site data analysis were completed. In order to rectify this situation and to provide meaningful relative performance ratios, the tracking data was revised so that each measure was set equal to the recommended savings value from the

Massachusetts Technical Reference Manual for 2011 Program Year – Report Version (Report 2011). Table 7 provides a summary of the tracking system revisions at the measure level, which shows that the revised tracking savings increased for both condensing boilers and condensing furnaces by 12%. The revised tracking savings for condensing furnaces, infrared heating and indirect water heater measures resulted in decreases of 41%, 41% and 32% respectively. After the revision the total tracking savings decreased by 4% (23,759 therms).

Table 7: Summary of Tracking System Revisions

Description	Original Tracking Savings (Therms)	Revised Tracking Savings (Therms)	Percent Change
Condensing Boiler	439,823	494,087	12%
Condensing Furnace	62,193	36,720	-41%
Infrared Heating	78,120	46,425	-41%
Indirect Water Heater	65,360	44,505	-32%
Total	645,496	621,737	-4%

4. Description of Methodology

4.1 Measurement and Verification Plans

DNV KEMA developed measurement and verification (M&V) templates for the four study measures that were approved by the PAs prior to implementation. The use of templates ensures data quality and consistency. The M&V templates contained the following:

- An overview of the measure and its relative contribution to energy savings;
- A description of the analysis methods;
- Identification of the key savings calculation inputs required for analysis;
- The proposed monitoring approach; and,
- Verification methodology.

Specific details of the M&V plans for each measure are reported in the measure level Appendices A - D.

5. Results

DNV KEMA installed 222 data recording devices to measure the performance of 86 incentivized units. For some sites that had multiple types of measures installed, e.g. a site where both a condensing boiler and an indirect water heater were present, if only one measure was drawn for the sample, both may have been monitored. These monitored data were used in conjunction with billing data to create calibrated regression models that were utilized to develop on-site savings estimates for the four evaluated measures. The verified estimate of savings and the tracking system estimate of savings were used to develop a stratified ratio estimate of program savings.

Equation 1 shows the ratio estimator. In this equation "y" denotes the onsite verified estimate of savings, "x" denotes the tracking system estimate of savings, and "w" denotes the case weights.

Equation 1: Combined Ratio Estimation

Ratio Estimate | Mean | Total

$$\hat{B}_0 = \frac{\sum_{i=1}^{n_0} w_i\, y_i}{\sum_{i=1}^{n_0} w_i\, x_i} \qquad \bar{y}_0 = \hat{B}_0\, \mu_{x0} \qquad \hat{Y}_0 = \hat{B}_0\, X_0$$

$$\text{where} \quad w_i = N_h / n_h$$

In addition to the estimate of the mean savings and the population total of saving, the statistical precision associated with each variable estimate was also estimated. Equation 2 presents the three steps necessary to calculate the statistical precision associated with our combined stratified ratio estimator.

Equation 2: Calculating the Statistical Precision

1. Calculate the residuals $e_i = y_i - \hat{B}_0\, x_i$
2. Calculate $se\left(\hat{B}_0\right) = \left(\frac{1}{\hat{X}_0}\right)\sqrt{\sum_{i=1}^{n_0} w_i\left(w_i - 1\right) e_i^2}$

   with $\hat{X}_0 = \sum_{i=1}^{n_0} w_i\, x_i$
3. Then $se\left(\bar{y}_0\right) = se\left(\hat{B}_0\right)\mu_{x0}$ and $se\left(\hat{Y}_0\right) = se\left(\hat{B}_0\right) X_0$

5.1 Program Savings Results

Table 8 presents the savings estimates by measure type. The estimated savings for boilers was 530,543 therms, for an overall relative performance[7] of 107% (based on the adjusted tracking savings). The estimated savings for furnaces was 58,696 therms, for an overall relative performance of about 160%.[8] The estimated savings for infrared heating was 9,105 therms, for an overall relative performance of about 20%. The estimated savings for indirect water heaters was 34,948 therms, for an overall relative performance of 78.5%. Overall, the relative performance for the four measures was about 102%. The results show that the analysis achieved the targeted statistical precision of ±25% for the condensing boiler and indirect water heater measures, but the overall total precision was ±15.6%.

Table 8: Program Savings Analysis Results

Description	Revised Tracking Savings (Therms)	On-site Total Savings (Therms)	Relative Performance	Relative Precision
Condensing Boiler	494,087	530,543	107.4%	±18.2%
Condensing Furnace	36,720	58,696	159.8%	±43.8%
Infrared Heating	46,425	9,105	19.6%	±27.7%
Indirect Water Heater	44,505	34,948	78.5%	±16.2%
Total	621,737	633,293	101.9%	±15.6%

The following sections of this report describe the process used to develop measure-level savings estimates and the findings of this evaluation. The program savings result was calculated by expanding the sample data to both the full population and the full year using regression models.

5.1.1 Meteorological Impacts

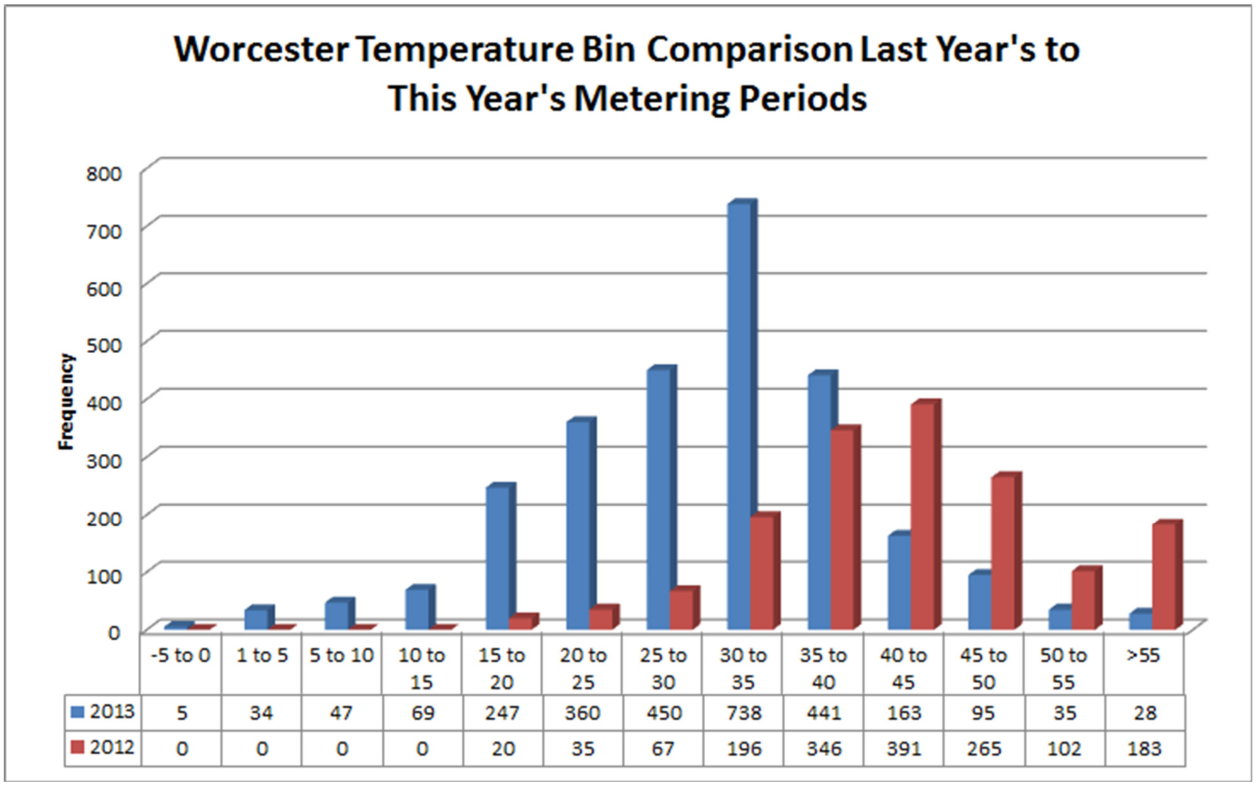
One of the primary concerns with the PY2010 evaluation was that the relatively warm weather that occurred during the metering period (February 2012 to April 2012) may produce bias modeled savings results for the heating measures. In order to help mitigate this issue DNV KEMA started the evaluation process earlier in the season. Meter installations began at the heating sites during the first week in December 2012 and extended to the second week of March 2013 to maximize the probability of metering during cold weather periods.

Figure 1 below shows the relative distribution of outdoor temperatures for the two monitoring periods.

[7] Relative performance is the ratio of the on-site savings divide by the revised tracking savings.

[8] The high relative performance for the therms is somewhat deceiving and is due to a tracking savings quantity issue. Two of the sample sites had two (2) furnaces installed, but only had savings for one furnaces recorded for the site.

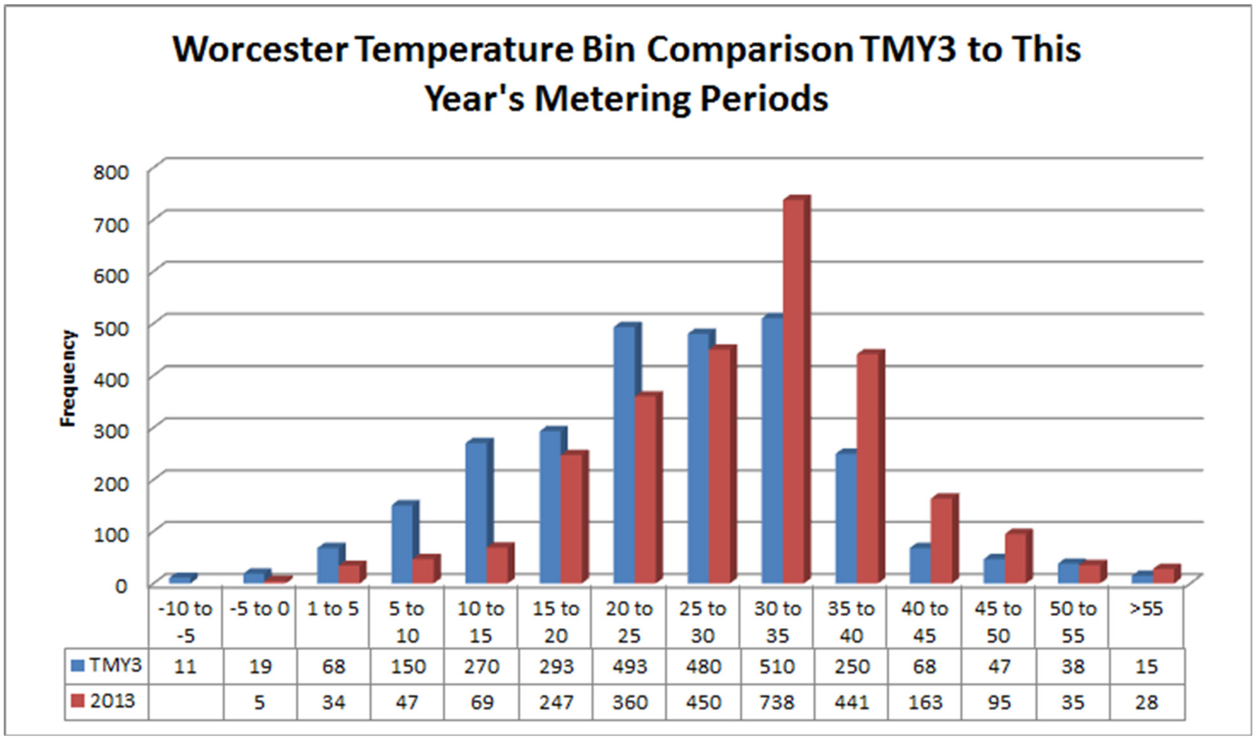
Figure 1: Temperature Bin Comparison PY2010 to PY2011



	-5 to 0	1 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50	50 to 55	>55
2013	5	34	47	69	247	360	450	738	441	163	95	35	28
2012	0	0	0	0	20	35	67	196	346	391	265	102	183

This graphic shows that overall the metering period for the PY2011 evaluation was substantially colder than that of the PY2010 study. Figure 2 below compares the PY2011 metering period to TMY3, the reference used to expand the measured sample to the full year. The heating demand during this metering period was substantially closer to that represented by the statistical norm of the TMY3 data.

Figure 2: TMY3 to PY2011 Metering Period Temperature



Based on the fit between the TMY3 and PY2011 temperature distribution, and the convergence of evaluated values across the two evaluation cycles, in particular the EFLH for condensing boilers, we are confident that our model appropriately accounts for the variations in temperature.

5.2 Measure Level Findings

The next five sections of this report will discuss the measure level findings for the condensing boiler, condensing furnace, infrared heater, indirect water heater and programmable thermostat measures. Throughout this discussion there are numerous figures that utilize consistent variable naming convention. Table 9 provides a description of each variable, as well as its type, source and date.

Table 9: Figure Variable Description

Variable Name	Description	Type	Source	Date
PY 2010	Sample value from PY 2010 Evaluation	Point Value	KEMA Evalaution PY 2010 Final Report	June 2012
PY 2011	Sample value from PY 2011 Evaluation	Point Value	KEMA Evalaution PY 2011 Final Report	June 2013
2009 TRM	Prescriptive savings value	Reference	MA TRM PY 2011 -Plan Version	October 2010
2011 TRM	Prescriptive savings value	Reference	MA TRM PY 2011 -Report Version	August 2012
2012 KEMA	Calculated mean value for PY 2010	Mean Value	KEMA Evalaution PY 2010 Final Report	June 2012
2YR Mean	Calculated mean value for PY 2010 & PY2011	Mean Value	KEMA Evalaution PY 2011 Final Report	June 2013

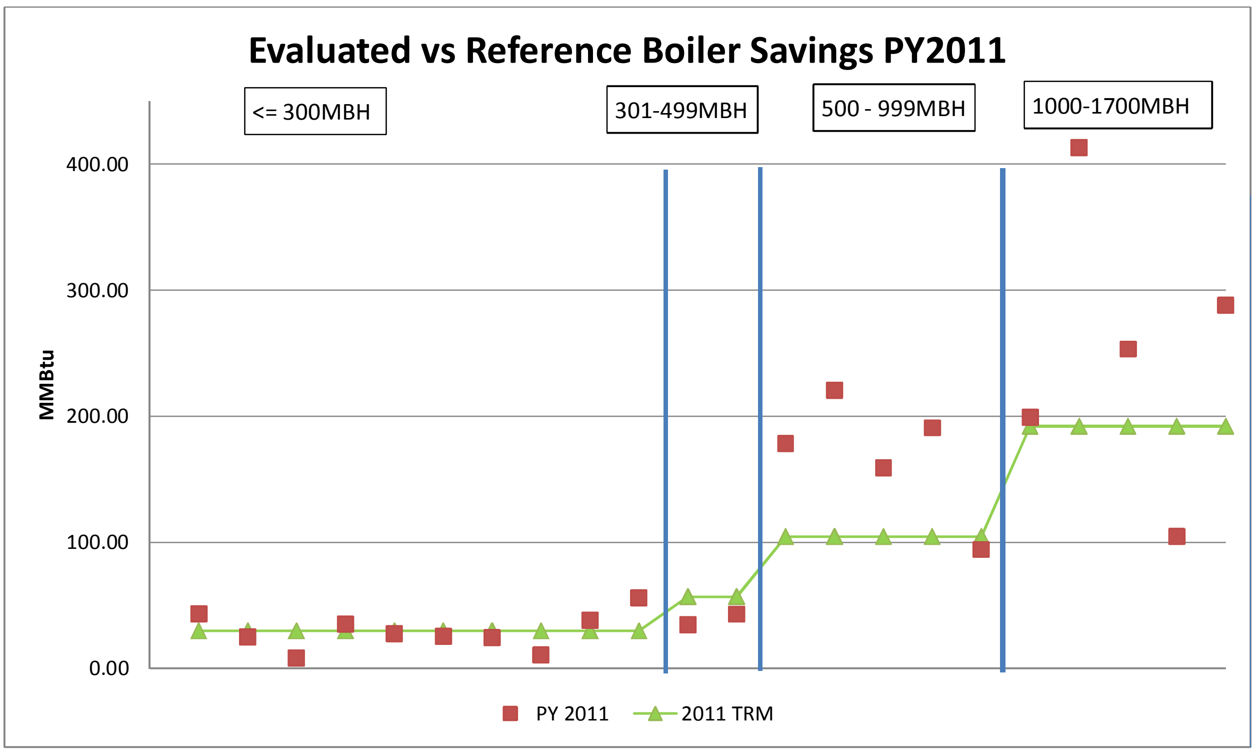
5.3 Condensing Boilers Findings

The following sections provide a discussion of the evaluation results observed for condensing boiler projects in Program year 2011 first and then discuss the results of the of the comparison and synthesis with the PY2010 boiler evaluation.

5.3.1 PY2011 Boiler Savings

Figure 3 plots the on-site evaluated savings for the boilers compared to the values the 2011 Report TRM form August 2012, referenced as "2011 TRM" in the graphs throughout the document. Note that sample project savings in the two smaller size bins tend to be more tightly grouped around the 2011 TRM savings values. The sample project savings in the two larger size bins are more variable and are generally larger than the 2011 TRM savings values.

Figure 3: Evaluated On-site Boiler Savings

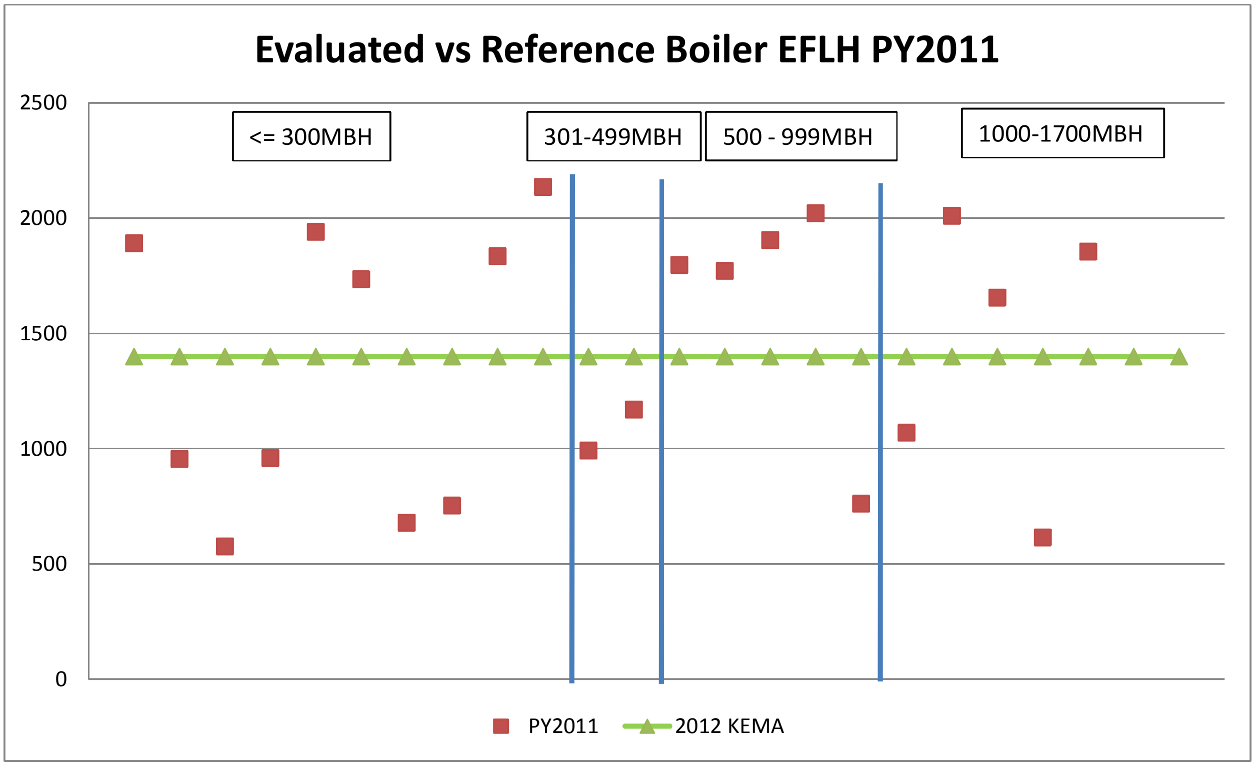


The next sections discus the factors that drive the difference between the tracked savings and the evaluated savings.

5.3.2 PY2011 Boiler Equivalent Full Load Hours (EFLH)

The difference between the hours of use (expressed in EFLH) incorporated in the DNV KEMA recommendations based on the PY2010 evaluation, referenced as "2012 KEMA" throughout this document, and the EFLH calculated from the data collected on-site, is one of the drivers for the increase in the calculated savings. Figure 4 below provides a graphical presentation of the comparison. The green line represents the 2012 KEMA recommended EFLH value of 1,400 hours and the graph shows that slightly more than half of the on-site EFLH values are above the TRM value. The mean EFLH observed in the sample was 1,412 hours, which is only about 1% higher than the 2012 KEMA value.

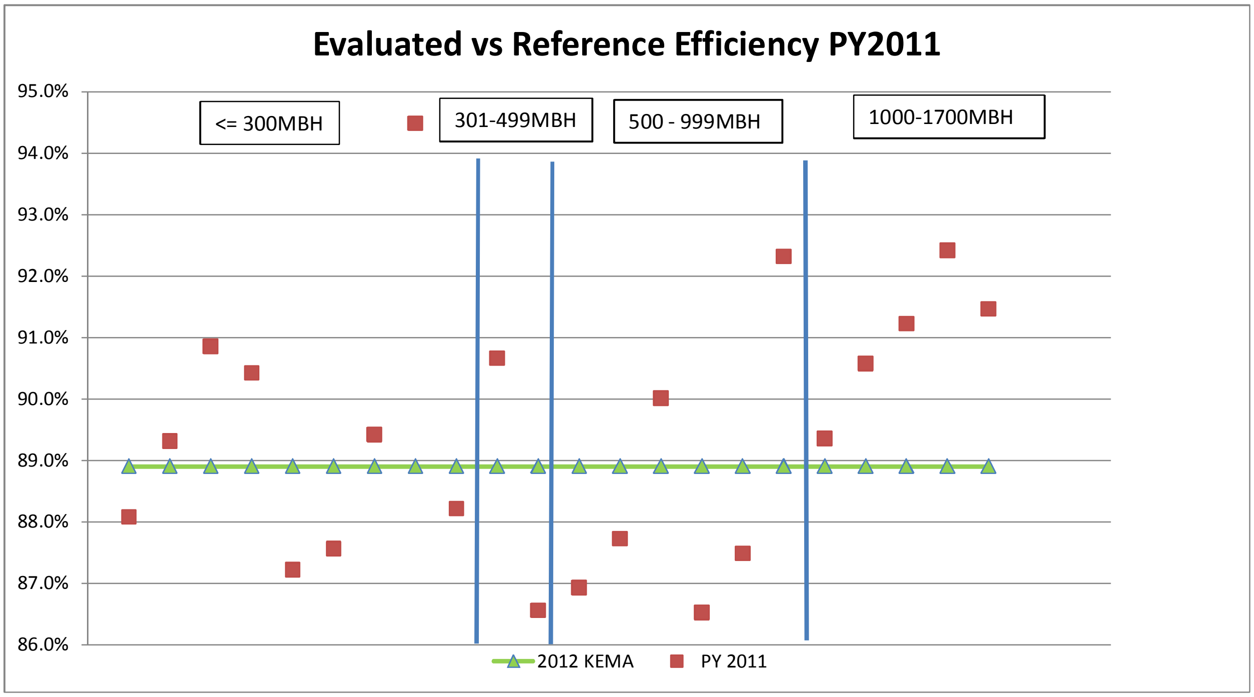
Figure 4: Evaluated On-site Boiler EFLH



5.3.3 PY2011 Efficiency

The difference between the on-site energy efficiency of the condensing boilers in the PY 2011 sample and the efficiency used to calculate the 2012 KEMA recommended savings is another contributing factor to the difference between the tracked and on-site savings. Figure 5 shows the calculated average efficiency of the installed equipment compared to the 2012 KEMA recommended value of 88.9%. Note that within each size category there are boilers operating above and below the reference line. The on-site boiler efficiency ranges between about 94.5% and 86.5% and the mean value observed in the PY 2011 sample increased to 89.5% (about 0.6%). In these data the largest boilers (1,000 -1,700 MBH) operate at higher average efficiency than the smaller boilers, with four of five operating above the reference efficiency and a mean efficiency of 90.1%.

Figure 5: Evaluated On-Site Boiler Efficiency



5.3.4 Summary of Boiler Findings

Table 10 provides the on-site savings estimates for each of the boilers evaluated, along with the capacity and calculated efficiency and EFLH.

Table 10: On-site Savings Variables by Boiler

Site ID	Unit	Type	Size Bins	2011TRM Savings	On-Site Savings	On-Site Capacity	On-Site EFLH	On-Site Efficiency
101	unit_1	Residential Multifamily	<300 MBH	29.4	43.17	203	1,890	88.1%
101	unit_2	Residential Multifamily	<300 MBH	29.4	24.76	203	955	89.3%
158	unit_1	Office	<300 MBH	29.4	8.13	96	577	90.9%
165	unit_1	Residential Multifamily	<300 MBH	29.4	35.15	255.2	959	90.4%
201	unit_1	Residential Multifamily	<300 MBH	29.4	27.28	139	1,939	87.2%
201	unit_2	Residential Multifamily	<300 MBH	29.4	25.41	139	1,734	87.6%
224	unit_1	Retail Business	<300 MBH	29.4	24.15	274	678	89.4%
259	unit_1	Community Center	<300 MBH	29.4	10.59	74	752	94.5%
259	unit_1	Residential Multifamily	<300 MBH	29.4	38.10	183	1,833	88.2%
259	unit_2	Residential Multifamily	<300 MBH	29.4	55.83	183	2,135	90.7%
146	unit_1	Residential Multifamily	301-499 MBH	56.1	34.67	377	991	86.6%
146	unit_2	Residential Multifamily	301-499 MBH	56.1	42.85	377	1,169	86.9%
176	unit_1	Public Assemebly - Museum	500-999 MBH	103	178.30	941	1,797	87.7%
180	unit_1	Residential Multifamily	500-999 MBH	103	220.69	927	1,770	90.0%
180	unit_3	Residential Multifamily	500-999 MBH	103	159.09	927	1,904	86.5%
180	unit_4	Residential Multifamily	500-999 MBH	103	190.69	927	2,020	87.5%
244	unit_2	Residential Multifamily	500-999 MBH	103	94.26	752	761	92.3%
114	unit_1	Univeristy - Atheletic Center	1000-1700 MBH	189.2	199.00	1440	1,069	89.4%
114	unit_2	Univeristy - Atheletic Center	1000-1700 MBH	189.2	413.06	1440	2,009	90.6%
136	unit_1	Univeristy - Residence Hall	1000-1700 MBH	189.2	253.25	1019	1,655	91.2%
136	unit_2	Univeristy - Residence Hall	1000-1700 MBH	189.2	104.54	1019	615	92.4%
136	unit_3	Univeristy - Residence Hall	1000-1700 MBH	189.2	287.97	1019	1,854	91.5%

5.3.5 Multiyear Comparison

This section presents a comparison of the evaluated savings for condensing boilers for program years 2010 and 2011. After three successive evaluations of this measure, evaluated findings to support prescriptive savings estimates have substantially converged, as shown in Table 11 below.

Table 11: Consolidated Boiler Findings, PY2010 & PY2011

Size Bins (Mbtu/hr)	Counts		Savings		EFLH		Efficiency	
	2010	2011	2010	2011	2010	2011	2010	2011
<300	3	10	37.9	29.3	2,317	1,345	87.8%	89.6%
301-499	5	2	61.4	38.8	1,412	1,080	88.4%	86.7%
500-999	5	5	70.1	168.6	1,167	1,650	86.6%	88.8%
1000-1700	2	5	218.9	251.6	1,613	1,440	87.7%	91.0%
1701+	9	NA	350.4	NA	1,226	NA	91.1%	NA
MEAN /Total	**24**	**22**	**181.8**	**112.3**	**1,421**	**1,412**	**88.9%**	**89.5%**

The difference in the mean savings between PY 2010 and PY 2011 is due to the difference in distribution of equipment capacity between the program years. The absence of boilers over 1,700 MBtu/hr in the

PY2011 sample significantly reduced the mean savings. As a point of reference, mean savings for the PY2010 sample absent this size boiler would have been 97.1 MMBtu.

Figure 6 below shows the evaluated savings of the samples for PY 2010 and PY 2011 against two reference points, the values adopted in the technical reference manual for PY 2009 ("2009 TRM") and the 2011 TRM recommended savings values, defined above.

Figure 6: Evaluated Boiler Savings PY2010 & PY2011

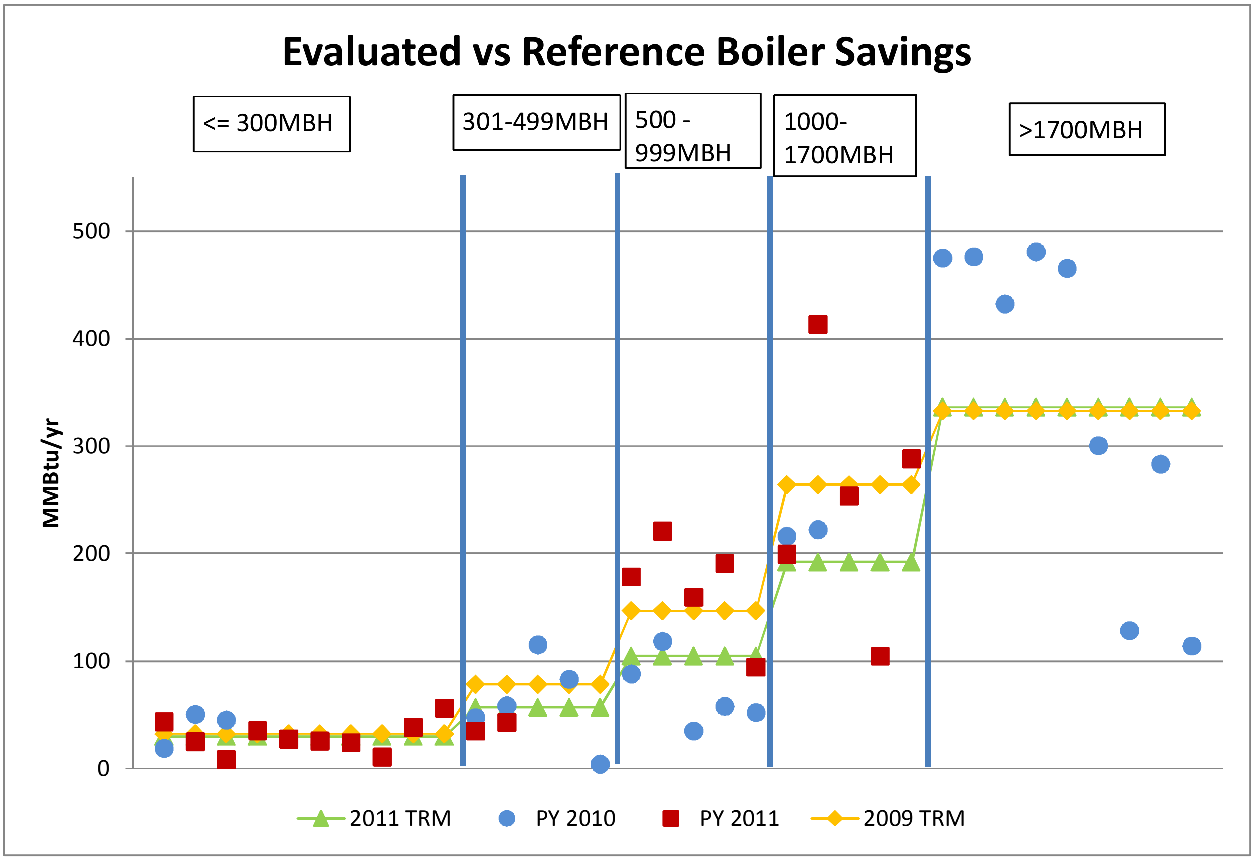


Figure 7 shows the distribution of EFLH for the same two program year samples against the same reference points. The 2009 TRM EFLH value is 1,500 hours and the 2012 KEMA EFLH value is 1,400 hours. There is a fairly broad range of EFLH, which are generally between about 2,300 hours and 500 hours. Note that the one low hour boiler point observed in the PY 2010 sample was for a process boiler that was used for truck washing and had very low usage. Although there is a high amount of variation for the EFLH the value through the three evaluations appear to be converge at reasonably accurate mean of just over 1,400 hours.

Figure 7: Evaluated Boiler EFLH PY2010 & PY2011

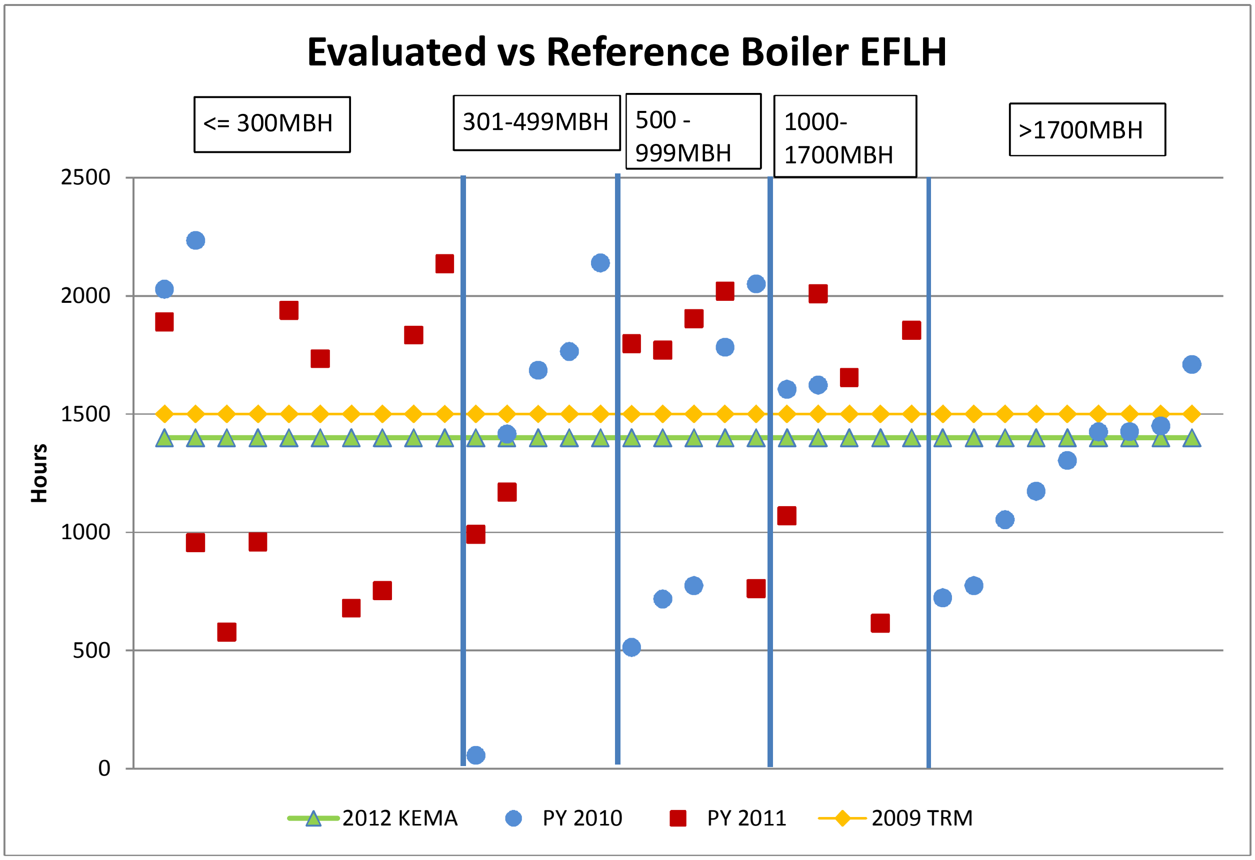
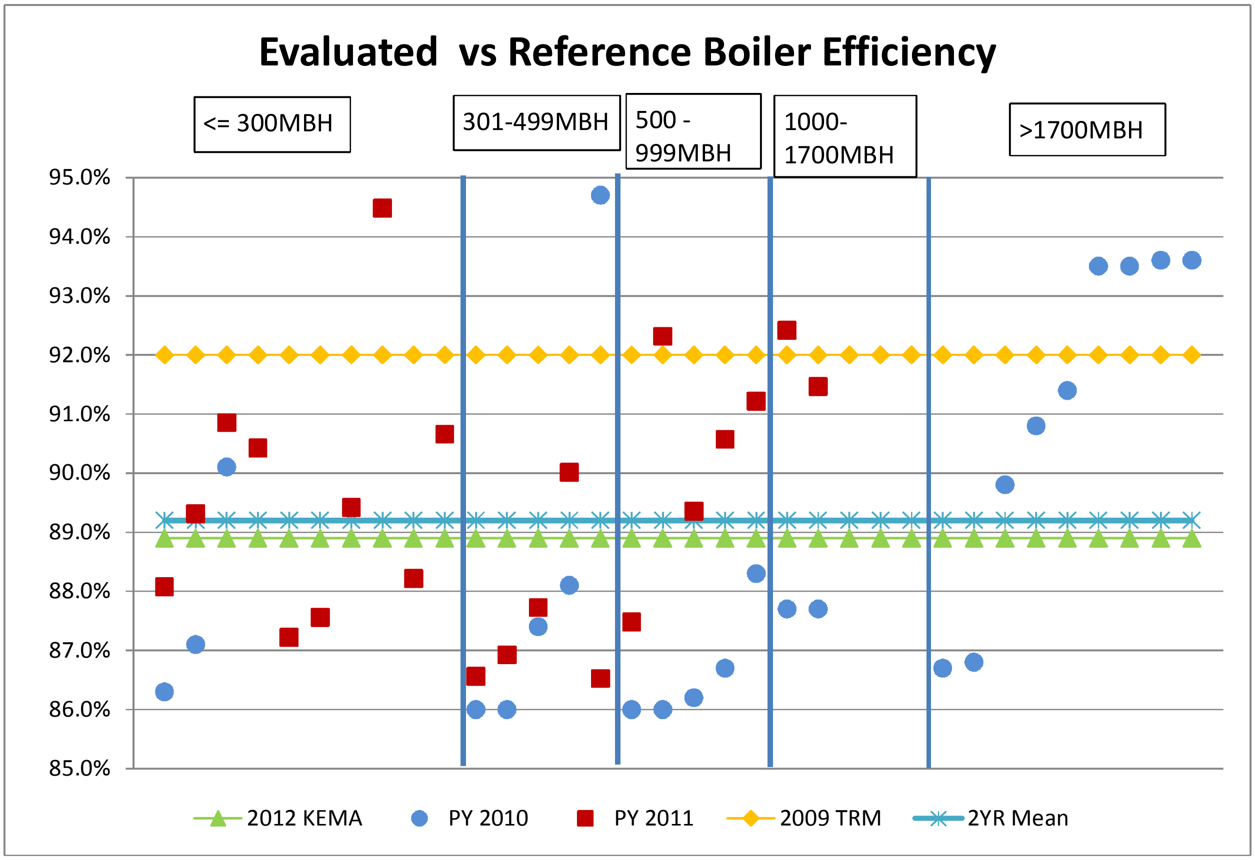


Figure 8 shows the evaluated efficiency of the sampled equipment for both program years along with the 2009 TRM efficiency value of 92% and the 2012 KEMA recommended efficiency value of 88.9% shown as reference lines. Once again, there is a fairly high amount of variability observed in the data with the boiler efficiency ranging from 86% to almost 95%. However, the mean efficiency does appear to be converging and the two-year mean value of 89.2% represents a good estimate of that value.

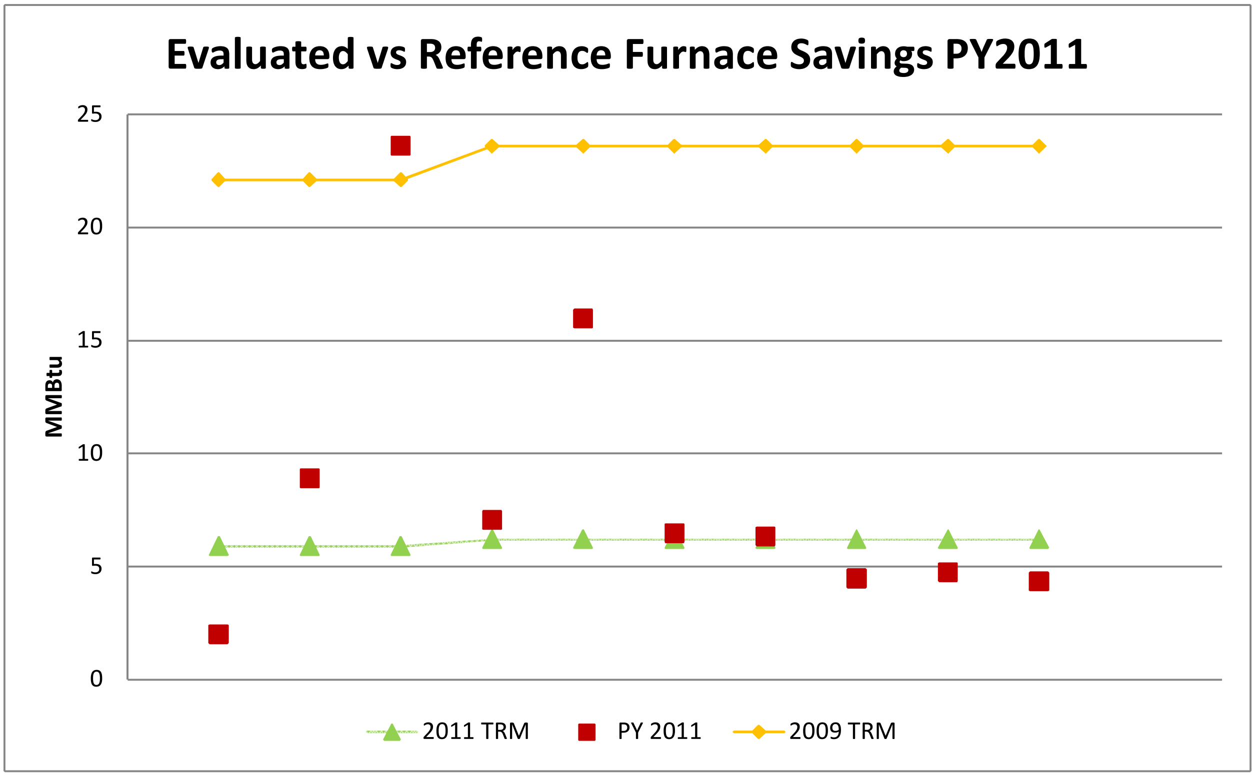
Figure 8: Evaluated Efficiency PY2010 & PY2011



5.4 Condensing Furnaces Findings

Figure 9 provides a graphical comparison of the on-site calculated savings compared to the 2011 TRM and 2009 TRM prescriptive savings values. The first three furnaces in are 92% efficiency bin and they have lower TRM savings values than the remaining 7 furnaces which are 94% + efficiency with ECM fan motors bin. Note that with the exception of two sites, all of the PY 2011 sample projects have savings that are tightly grouped around the 2011 TRM savings values. The overall mean annual savings for the PY 2011condensing furnace sample was 8.39 MMBtu/unit.

Figure 9: Evaluated On-Site Furnace Savings

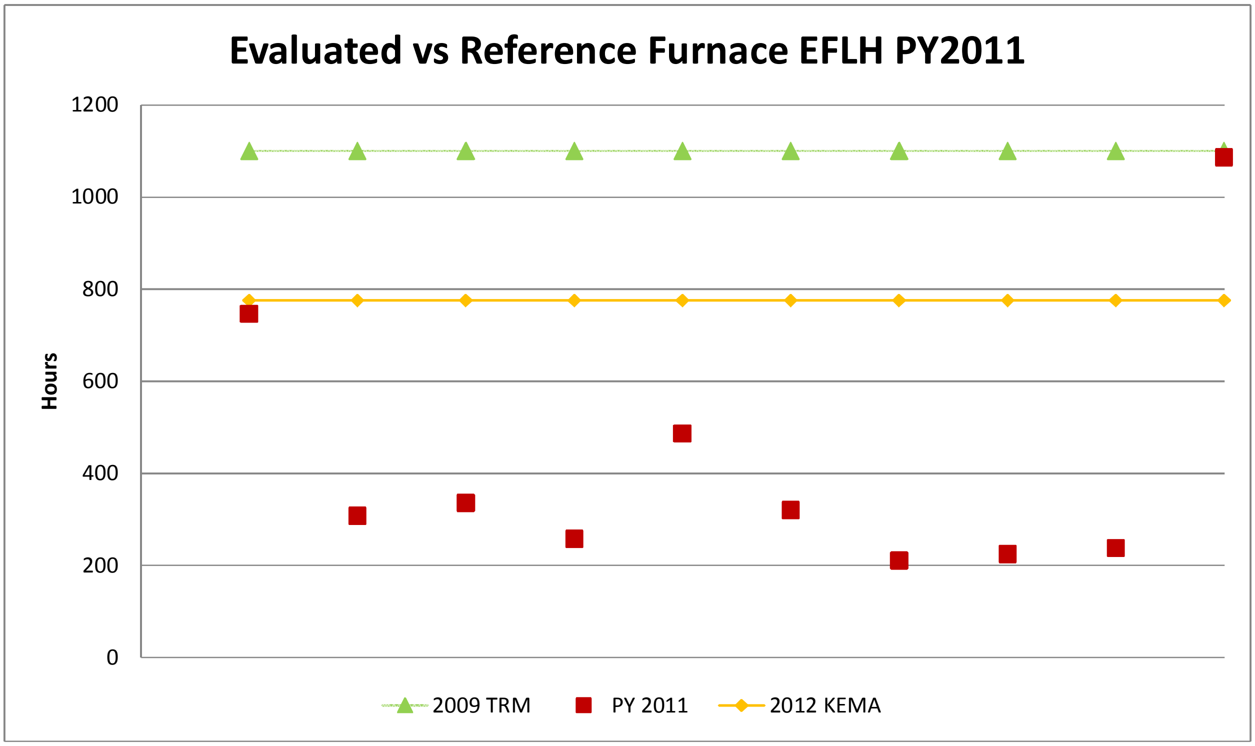


5.4.1 Furnace EFLH

As with condensing boilers, the difference in hours of use between the monitored equipment and the values contained in the TRM's prescriptive savings values is the primary driver for the difference in savings. Lower usage translates into lower savings. The calculated usage of the monitored furnaces, ranged between 210 and 1,086 EFLH for the monitored equipment, with an average of 421 hours.

Figure 10 below displays the calculated usage of the monitored equipment. Only the EFLH found at one site exceeded either of the reference values. Absent this sample point, the calculated usage for the remainder of the sample pool ranged between 210 and 746 EFLH, with an average of 347 hours.

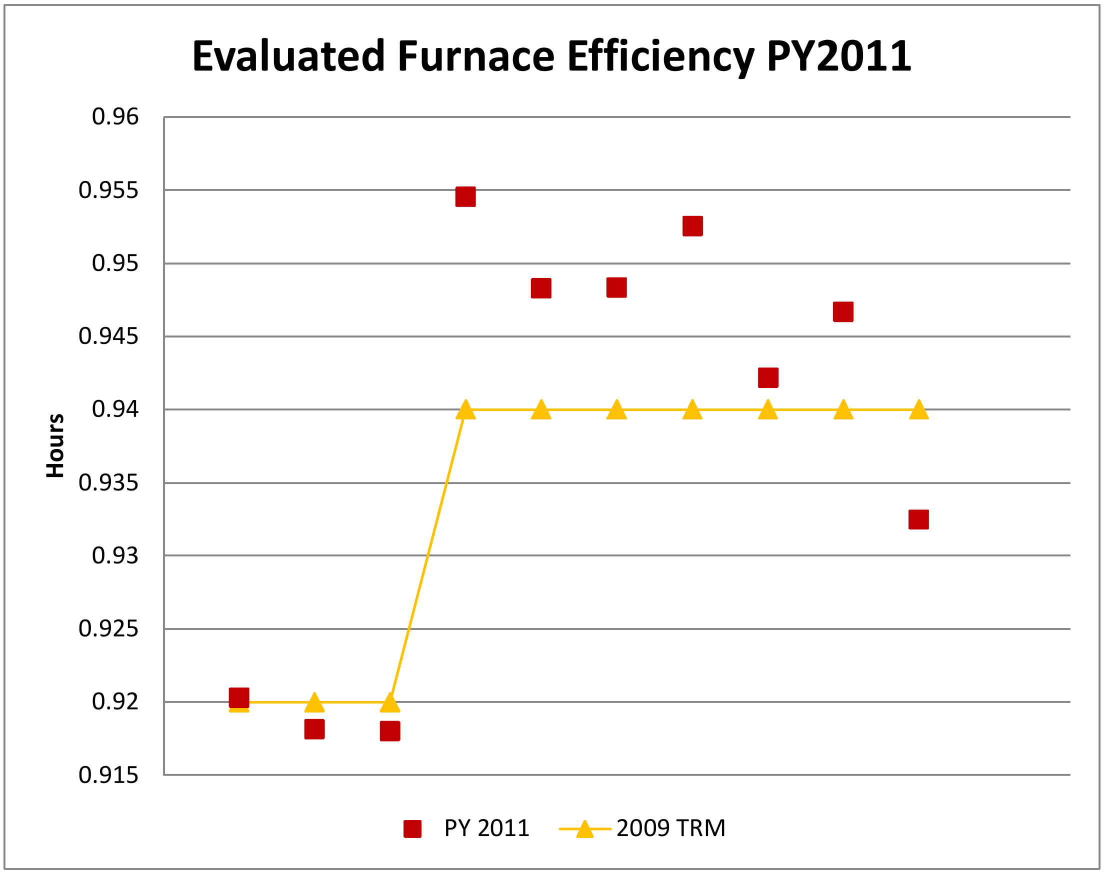
Figure 10: Evaluated On-Site Furnace EFLH



5.4.2 Furnace Efficiency

For PY2011 there were essentially two efficiency categories for condensing furnaces, one for furnaces that have a rated efficiency between 92% and 94% and another for furnaces that have a rated efficiency exceeding 94%. Figure 11 provides a graphical presentation of the on-site furnace efficiency data, which shows that there is little variance or divergence in this variable.

Figure 11: Evaluated On-Site Furnace Efficiency



5.4.3 Summary of Furnace Findings

Table 12 provides a listing of the furnace savings along with business type, capacity and EFLH.

Table 12: List of Furnace Savings Factors

Site ID	Business Type	Measure Description	2011 TRM Savings	On-site Savings	On-site EFLH	On-site Efficiency
178_FU_2	Service	FURNACE >= 92%	13.5	2.0	258	92.0%
221_FU_1	Religious	FURNACE >= 92%	13.5	23.6	1,086	91.8%
248_FU_2	School	FURNACE >= 92%	13.5	8.9	487	91.8%
117_FU_3	Office-medical	FURNACE >= 94% w ECM	14.9	6.3	320	95.5%
138_FU_2	Religious	FURNACE >= 94% w ECM	14.9	6.5	307	94.8%
138_FU_2	Religious	FURNACE >= 94% w ECM	14.9	7.1	335	94.8%
219_FU_4	Office-medical	FURNACE >= 94% w ECM	14.9	4.5	210	95.3%
126_FU_3	Restaurant (Pizza)	FURNACE >= 94% w ECM	14.9	4.8	225	94.2%
209_FU_2	Country club	FURNACE >= 94% w ECM	14.9	16.0	746	94.7%
250_FU_3	Warehouse	FURNACE >= 94% w ECM	14.9	4.3	237	93.2%

5.4.4 Multiyear Comparison

This section presents a comparison of the evaluated savings for condensing furnaces for program years 2010 and 2011. Table 13 provides a summary of the two-year evaluation findings for the savings and other key variables, which shows that generally the average savings, EFLH and efficiency are relatively stable. The savings and EFLH do show high variability within savings categories with small samples, but these higher values tend to be reduced when considered in the larger sample.

Table 13: Consolidated Furnace Findings – PY2010 & PY2011

Bins	Counts		Savings		EFLH		Efficiency	
	2010	2011	2010	2011	2010	2011	2010	2011
FURNACE => 92%	8	3	5.9	11.5	375	610	93.4%	91.9%
FURNACE => 92% w ECM	1	0	13.1	NA	870	NA	92.5%	NA
FURNACE => 94% w ECM	3	7	10.4	7.1	517	340	94.4%	94.6%
MEAN / Total	**12**	**10**	**7.7**	**8.4**	**452**	**421**	**93.6%**	**93.8%**

Figure 12 provides a graphical presentation of the condensing furnace on-site savings data for PY 2011 and PY 2010 along with the 2009 TRM and 2011 TRM savings values and the two-year mean savings estimate. The two-year mean savings for the 92% efficiency furnace is 7.46 MMBtu/unit and for the 94% + furnace with ECM it is 8.75 MMBtu/unit. The two-year mean efficiency provides savings estimates that represent an equally weighted combination of the evaluation results, which seems appropriate for this measure.

Figure 12: Evaluated Savings PY 2010 & PY 2011

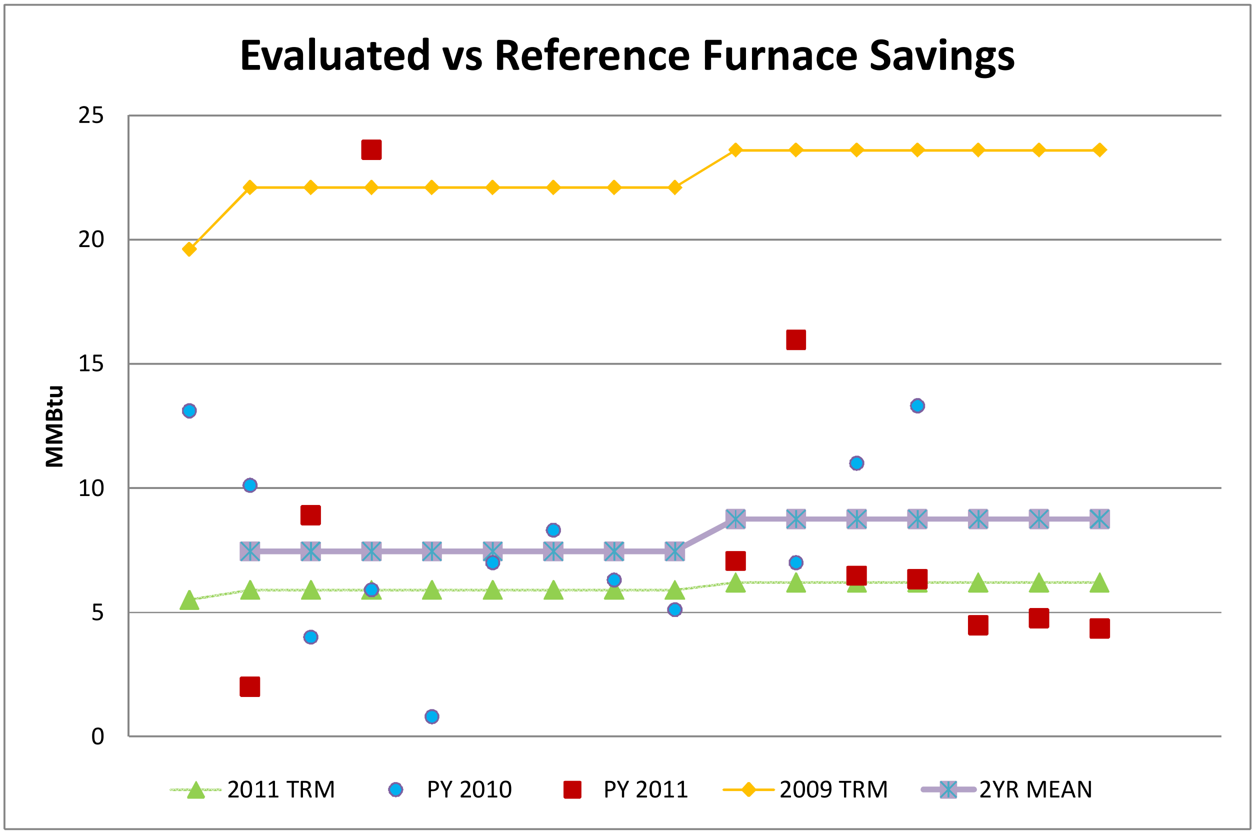
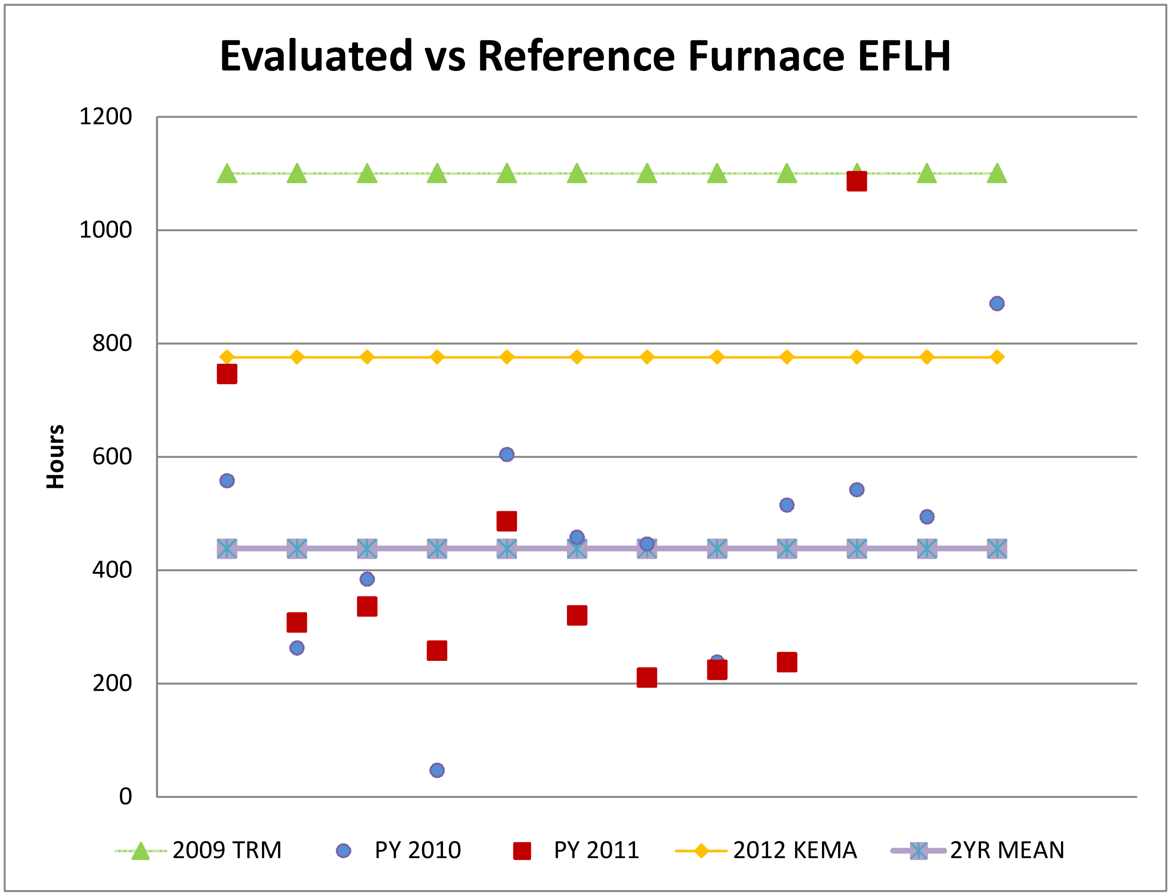


Figure 13 provides a graphical presentation of the combined EFLH for the condensing furnace on-site savings data for PY 2011 and PY 2010 along with the 2009 TRM and 2012 KEMA EFLH values and the two-year mean EFLH estimate. The 2009 EFLH value was estimated to be approximately 1,100 hours[9] and the 2011 TRM EFLH value is approximately 776 hours.[10] Note that for all but two of the sites the EFLH are significantly lower than both the 2009 TRM and 2012 KEMA values. The two year mean EFLH for the all of the furnaces is 432 hours and for most furnaces the EFLH is between 200 and 600 hours, which is abroad range, given the impact hours of usage have on savings. Of the three reference lines on the graph, the two-year average represents the best fit to the data. However, this is an extremely important variable and there is a large amount of variation within the sample that warrants further discussion.

[9] The mean capacity and efficiency assumptions were not defined so this is an estimated value.

[10] The KEMA recommended savings value was the mean savings between the PY 2010 on-site savings value and the 2009 TRM savings value.

Figure 13: Evaluated EFLH PY2010 & PY2011



Equivalent full load hours are largely site-specific and there are many factors that contribute to the variation observed in the data. This is the second year that the EFLH observed for the on-site sample of condensing furnaces was lower than expected and there are a variety of reasons that can cause this to occur. There were several factors that contribute to the low operating hours observed in the sample as follows;

- Low operating hours of the facility or space served by the furnace,
- Furnace heating capacity is oversized for the space served,
- Additional heating sources already serving the space, and
- Use of programmable thermostats with aggressive setback settings.

Table 14 provides the unit level savings for the condensing furnaces in the PY 2011 sample along with an explanation of the factors at the site that influenced the operation of the equipment.

Table 14: Examination of Condensing Furnace Savings Factors

Condensing Furnace Findings PY2011 - Explanation of Outliers						
Site ID	Unit	Business Type	On-site Savings (MMBtu)	EFLH	Exception Category	Contributing Conditions
126	1	Restaurant	4.8	225	Low savings	Pizza ovens reduced space heat demand
138	1	Religious	6.5	307	Low savings	Minimal usage due to occupancy schedule and other heat sources
138	2	Religious	7.1	335	Low savings	Minimal usage due to occupancy schedule and other heat sources
178	1	Service	2.0	258	Low savings	Low set point, small area served, and other heat source
209	1	Country club	16.0	746	High savings	Zone overlap with other heat sources, occupancy driven usage
221	1	Religious	23.6	1,086	Highest savings	Zone overlap with other heat sources, lead of 3 supplemental units
248	2	School	8.9	487	Low savings	Low set point, off except for school hours.
250	1	Retail	4.3	237	Low savings	Warehouse with low set point, low operating hours

Although there are not many resources available that provide predicted values for C&I furnace EFLH, Table 15 below summarizes the usage developed for Providence RI, which shows that with a temperature setback the predicted EFLH for office and retail are within the range of the values observed in the on-site samples.[11]

Table 15: Heating Equipment EFLH by Building Type

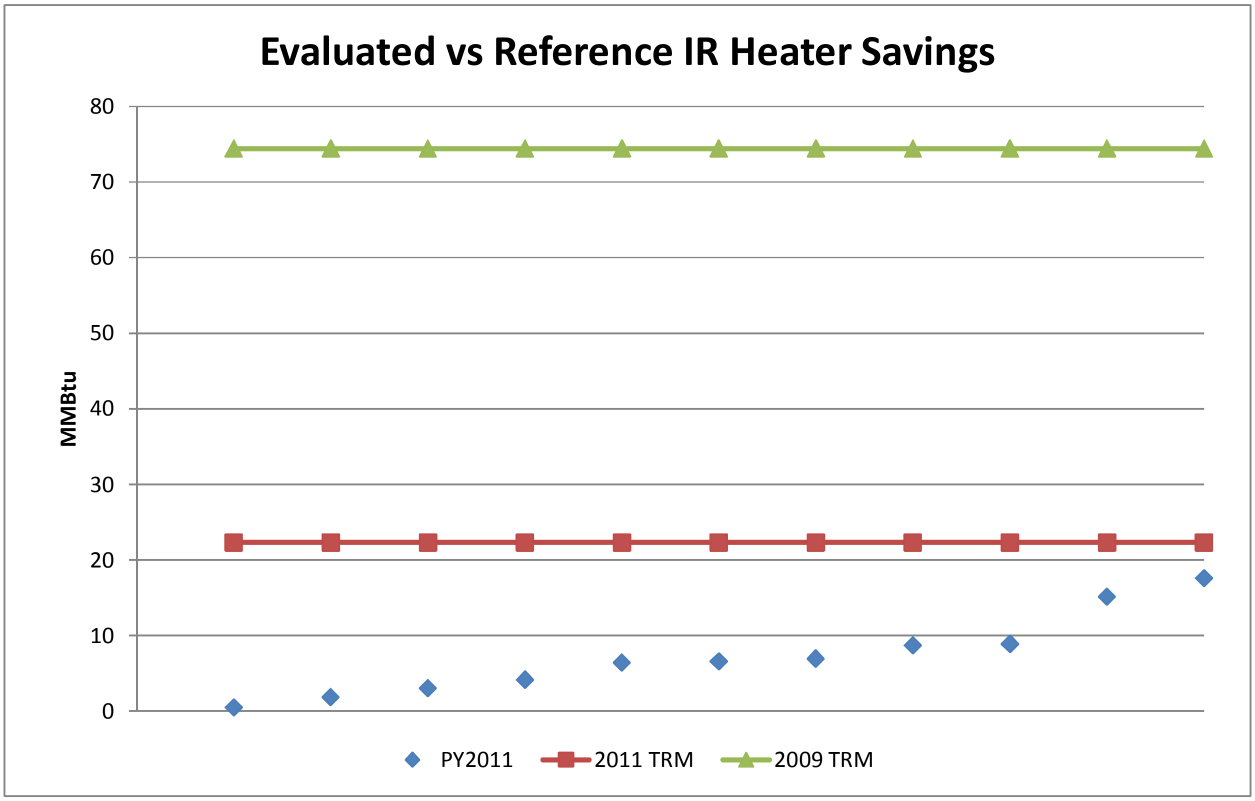
	Building Type						
Location: Providence RI	Assembly	Education	Food Service	Lodging	Office	Retail	Warehouse
With Temperature Setback	1894	795	1388	1523	504	454	740
Without Temperature Setback	1927	1272	1269	1523	972	1207	1074

[11] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (DOE-EERE). 2000. *Energy Conservation Program for Consumer Products: Screening Analysis for EPACT-Covered Commercial HVAC and Water-Heating Equipment Screening Analysis*. DOE-EERE, Washington, D.C.

5.5 Infrared Heaters Findings

Figure 14 provides graphical comparison of the PY 2011 on-site savings estimate to the 2009 TRM and 2012 KEMA recommended savings values for infrared heaters (IR heaters). The onsite savings are significantly lower than either of the two reference values. The average annual savings for PY 2011 IR heaters was 7.2 MMBtu/unit, significantly less than either the 2009 TRM value of 74.4 MMBtu/unit or the 2012 KEMA value of 48.3 MMBtu/unit.

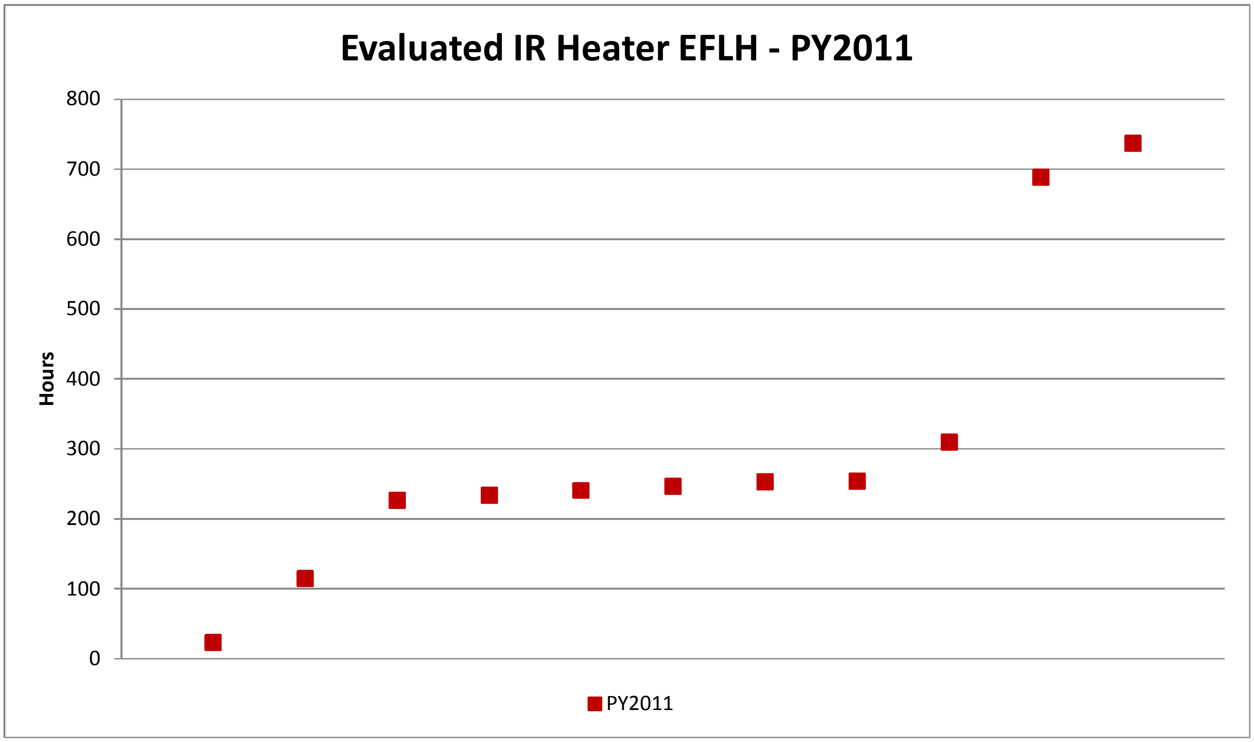
Figure 14: Infrared Heater Savings – On-site to 2011 TRM Values



5.5.1 Infrared Heater EFLH

As shown in Figure 15 the EFLH was highly variable within the PY 2011 sample ranging from a low of 23 hours to a high of 737 hours and the mean value was 302 hours.

Figure 15: Evaluated Usage



5.5.2 Summary of Infrared Heater Findings

Table 16 provides a summary of the tracking and on-site savings along with a listing of the variables that were utilized to develop the savings estimates.

Table 16: Infrared Heaters Summary of Savings

Site ID	Unit ID	Business Type	Measure Description	TRM Savings	On-site Savings	On-site Capacity (MBTU)	On-site EFLH
134N	3	Skating Rink	IR Heater	48.3	4.16	75	253
134S	3	Skating Rink	IR Heater	48.3	1.88	75	114
145	3	Warehouse	IR Heater	48.3	0.44	75	23
213	1	Warehouse	IR Heater	48.3	15.11	100	688
213	3	Warehouse	IR Heater	48.3	6.41	125	234
233	2	Machine shop	IR Heater	48.3	6.58	100	227
118	2	Warehouse	IR Heater	48.3	6.97	110	309
108	8	Manufacturing	IR Heater	48.3	17.54	125	737
131	2	Workshop	IR Heater	48.3	3.06	60	240
230	2	Garage	IR Heater	48.3	8.92	150	254
230	1	Garage	IR Heater	48.3	8.66	150	246

5.5.3 Multiyear Comparison

This section presents a comparison of the evaluated savings for condensing furnaces for program years 2010 and 2011. Table 17 provides a summary of the two-year evaluation findings for the savings and other key variables, which shows that generally the average savings, EFLH have dropped by about 50% between the PY 2010 and PY 2011 evaluations. The savings and EFLH do show high variability within savings categories with small samples, but these higher values tend to be reduced when considered in the larger sample.

Table 17: Consolidated Infrared Heater Findings – PY2010 & PY2011

Description	Counts		Savings		EFLH		Capacity	
	2010	2011	2010	2011	2010	2011	2010	2011
Infrared Heater	9	11	16.8	7.2	677	302	93	104

Figure 16 provides a graphical presentation of the infrared heater on-site savings data for PY 2011 and PY 2010 along with the 2009 TRM and 2011 TRM recommended savings values and the two-year mean savings estimate. The two-year mean annual savings for the infrared heaters is approximately 12.0 MMBtu/unit and provides an equally weighted combination of the evaluation results, which may not be entirely appropriate. There seems to be a distinction in the sample between applications where the heater are regularly used for comfort space heating and applications where the heaters are used for low temperature heating to keep products from freezing or on a really sporadic low use schedule.

Figure 16: Evaluated Savings PY 2010 & PY 2011

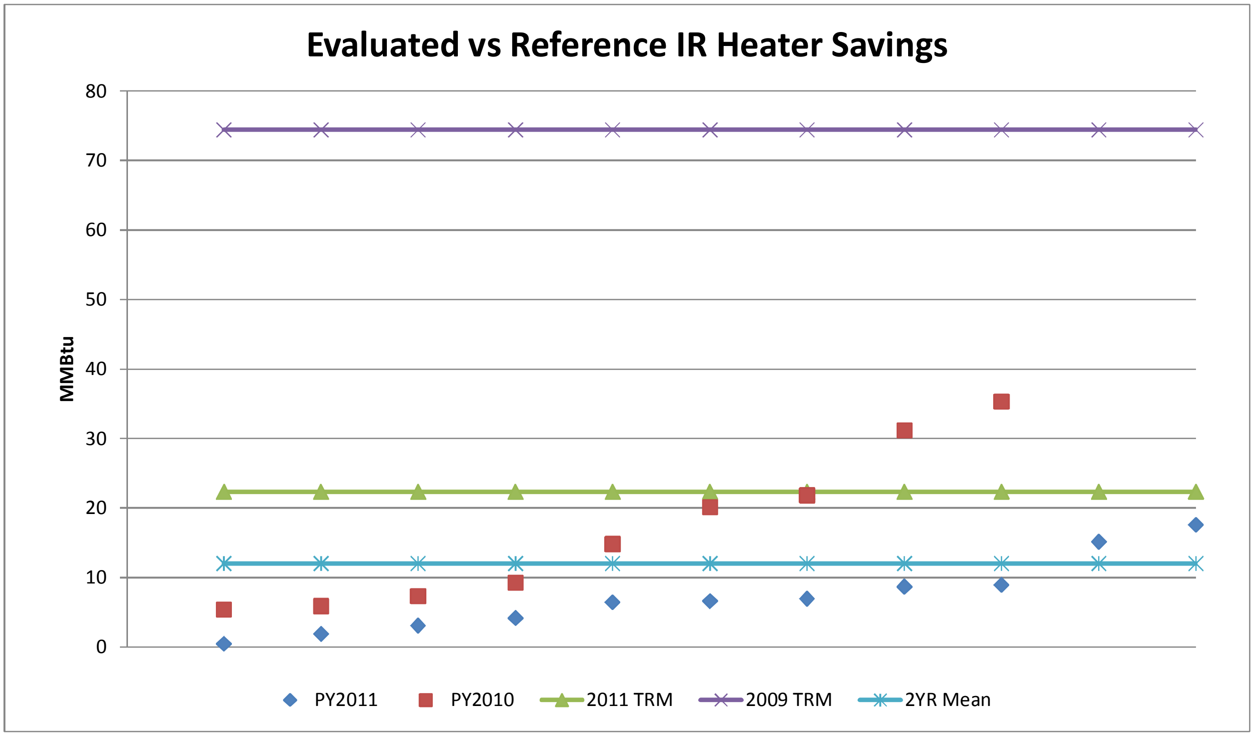
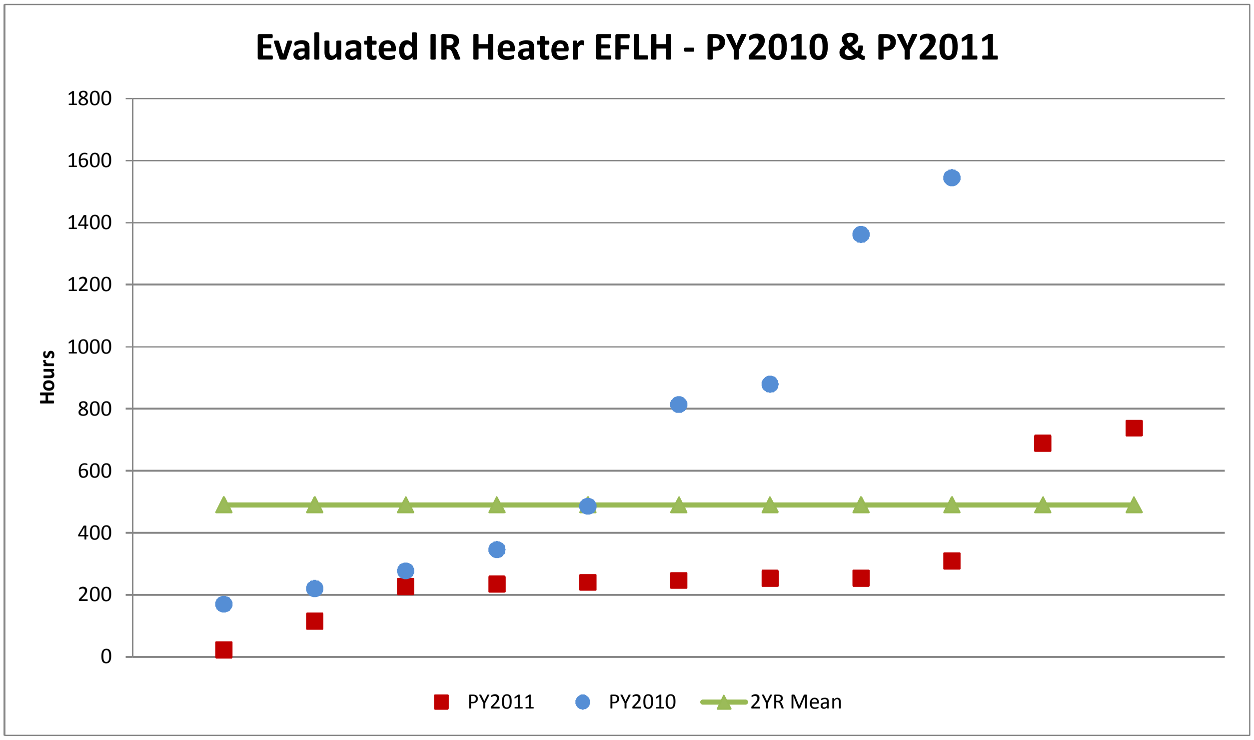


Figure 17 shows the on-site EFLH for PY 2010 and PY 2011 plotted along with the two year mean value of 490 hours. This graphic illustrates the issue of the duality of heating applications for this technology. The six units above the reference line and the one on the line are cases where the IR heater is the primary source of "comfort" heating in a space that is occupied on a regular basis. The units that are below the line consist of some combination of the following;

- Low operating hours of the facility or space served by the IR heater,
- Unusually low set point temperature (45ºF) used to keep product from freezing,
- Additional heating sources already serving the space, and
- Use of programmable thermostats with aggressive setback settings.

Figure 17: Evaluated EFLH PY 2010 & PY 2011



The mean annual savings for the seven highest use units is 22.3 MMBtu/unit, while the mean savings for the low use units is only about 5.8 MMBtu/unit. Table 18 provides the unit level savings for the infrared heaters in the PY2011 sample along with an explanation of the factors at the site that influenced the operation of the equipment.

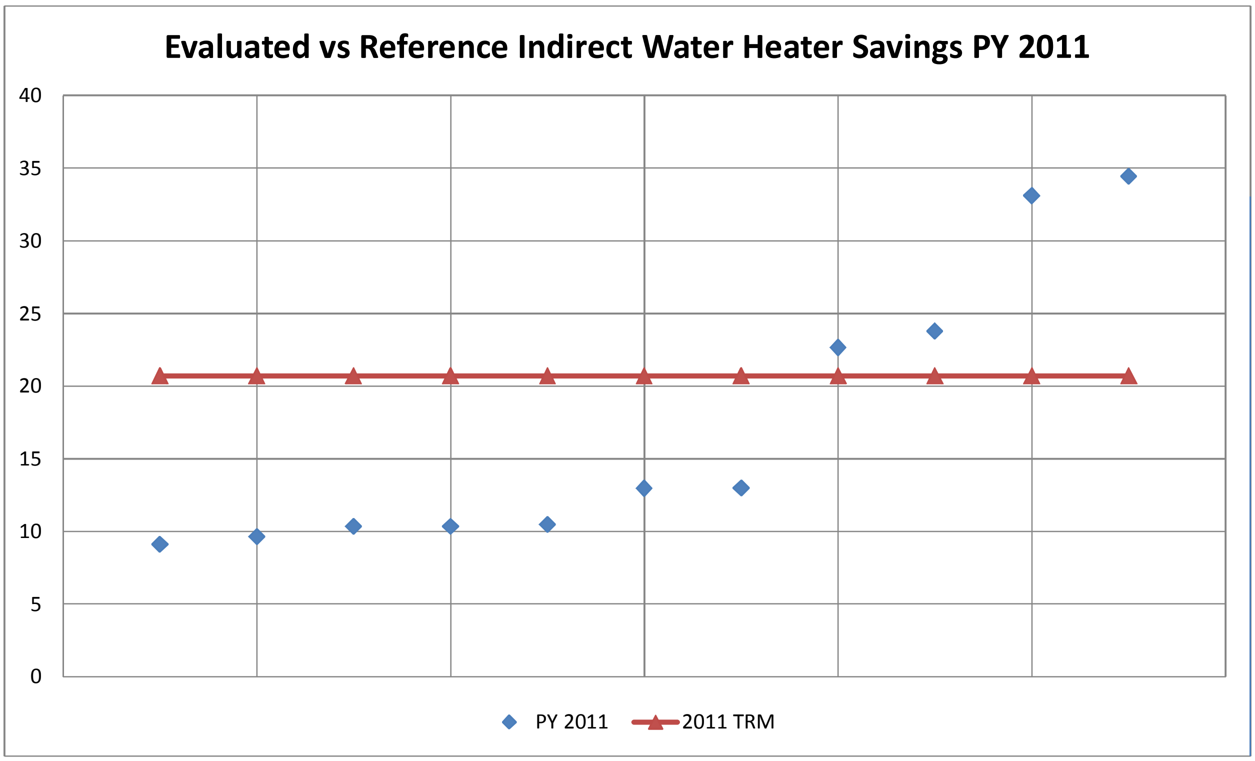
Table 18: Examination of Infrared Heater Savings Factors

Infrared Heater Findings PY2011 - Explanation of Outliers						
Site ID	Unit	Business Type	On-site Savings (MMBtu)	EFLH	Exception Category	Contributing Conditions
108	8	Manufacturing	17.5	737	Highest savings	High air exchange rate and reasonable set points
118	2	Warehouse	7.0	309	Low savings	Low usage and low set points in uninsulated zone.
134	N	Skating Rink	4.2	253	Low savings	Low and infrequent usage
134	S	Skating Rink	1.9	114	Low savings	Low and infrequent usage
145	3	Warehouse	0.4	23	Low savings	Low usage primarily to support process (pre-heat surface for paint)
213	1	Warehouse	15.1	688	Low savings	Set point just above freezing, low usage schedule
213	3	Warehouse	6.2	234	Low savings	Set point just above freezing, low usage schedule
230	2	Garage	8.9	254	Low savings	Low usage and low set points in uninsulated zone.
230	1	Garage	8.7	246	Low savings	Low usage and low set points in uninsulated zone.

5.6 Indirect Water Heaters Findings

The unweighted average annual savings for the eleven evaluated units is 17.2 MMBtu/unit, about 17% less than the 2012 KEMA value of 20.7 MMBtu/unit.[12] Figure 18 below comparing the calculated savings to the TRM prescriptive values. The standard deviation, or the dispersion of values from the mean, is 8.7 MMBtu, over half the average value. Given the uncertainty around the variables utilized to generate the original savings estimate, additional investigation may be warranted.

Figure 18: Indirect Water Heater Savings – On-site to 2011 TRM Values

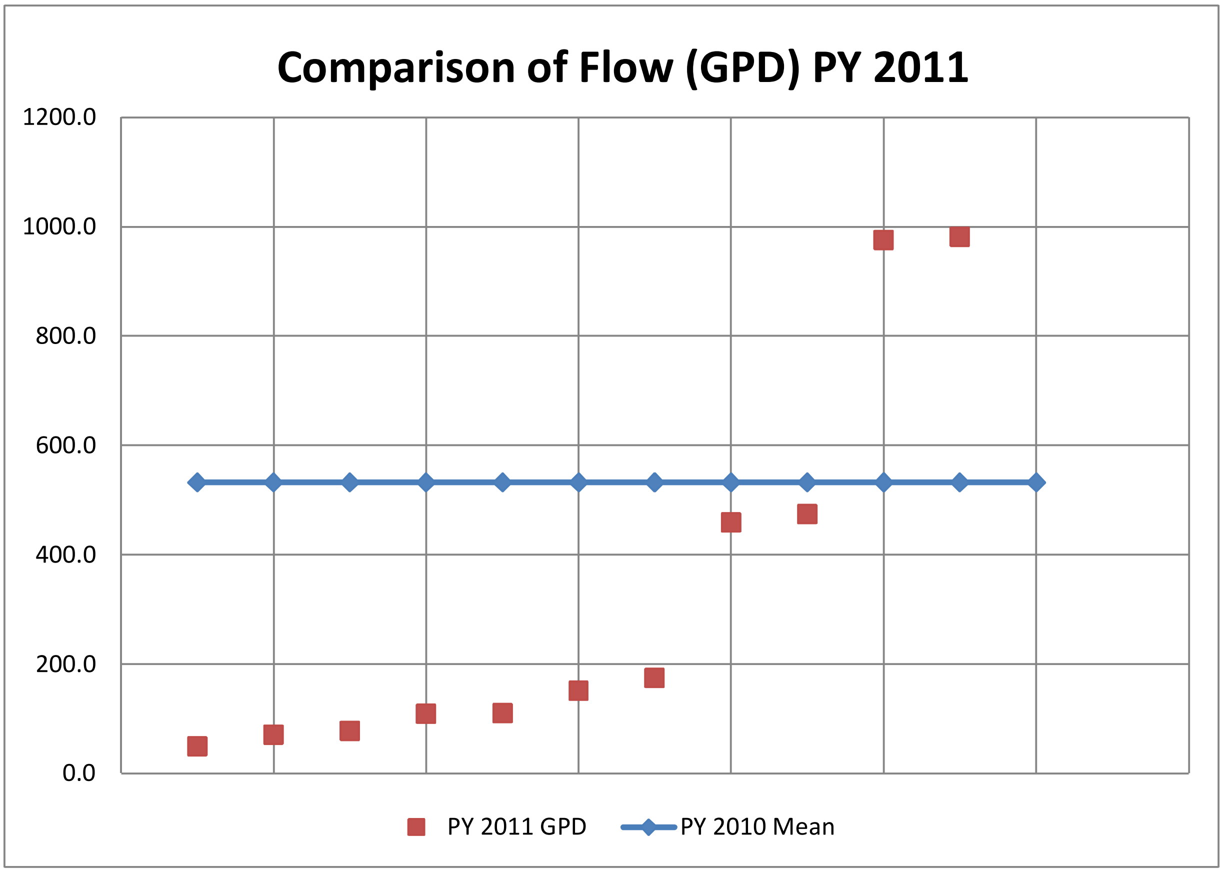


[12] The 2012 KEMA savings value for this measure represents the mean savings value for this measure as evaluated by DNV KEMA for the PY 2010 evaluation and reported in 2012.

5.6.1 Usage - Gallons per Day

Through examination of the sample data, we found that the primary explanatory metric for the difference range of savings calculated was the calculated daily demand for hot water, in gallons per day (GPD). Figure 19 below shows the comparison to the observed daily demand for hot water to the value determined by DNV KEMA in the evaluation of this measure last year, about 532 gallons per day.[13]

Figure 19: Tracking to On-Site Flow



5.6.2 Summary of Indirect Water Heater Findings

The unit-level findings are summarized in Table 19 below. Note that there is tremendous variation of savings even when units are installed at the same facility (site 166_WH_3) or at the same business type. There were a total of five units out of the eleven (45%) units that were classified as residential multifamily and this is significantly lower than PY 2010 where ten of twelve (83%) of the units were

[13] There was no direct measurement of hot water usage, the values are estimates calculated from other measured variables.

installed at residential multifamily facilities. In this sample, the office water heater has the lowest use as one would expect and the two shelter facilities also have low usage. Although the data clearly shows a distinction in the savings achieved between "high usage" sites and "low usage" sites, there is no clear indicator of which savings category a program participant would be in based upon business type.

Table 19: Findings Summary – Indirect Water Heaters

Site ID	Unit ID	Business Type	Measure Description	TRM Savings	On-site Savings	Capacity (gal)	On-site GPD	Boiler Efficiency
166_WH_3	unit_1	University	Indirect Water Heater	20.7	13.0	104	109	89.6%
166_WH_3	unit_2	University	Indirect Water Heater	20.7	22.7	104	459	89.6%
237_WH_1	unit_1	Shelter	Indirect Water Heater	20.7	9.1	60	71	91.8%
195_WH_1	unit_1	Res MF	Indirect Water Heater	20.7	23.8	45	474	91.8%
160_WH_1	unit_1	Res MF	Indirect Water Heater	20.7	10.3	65	110	89.9%
152_WH_2	unit_1	Restaurant	Indirect Water Heater	20.7	34.4	45	982	89.6%
244_WH_4	unit_2	Res MF	Indirect Water Heater	20.7	33.1	50	976	89.6%
163_WH_2	unit_1	Office	Indirect Water Heater	20.7	9.6	80	49	89.6%
104_WH_3	unit_1	Res MF	Indirect Water Heater	20.7	13.0	82	151	91.8%
259_WH_4(R)	unit_2	Res MF	Indirect Water Heater	20.7	10.3	23	174	90.8%
201_WH_4	unit_1	Shelter	Indirect Water Heater	20.7	10.5	80	78	89.9%

5.6.3 Multiyear Comparison

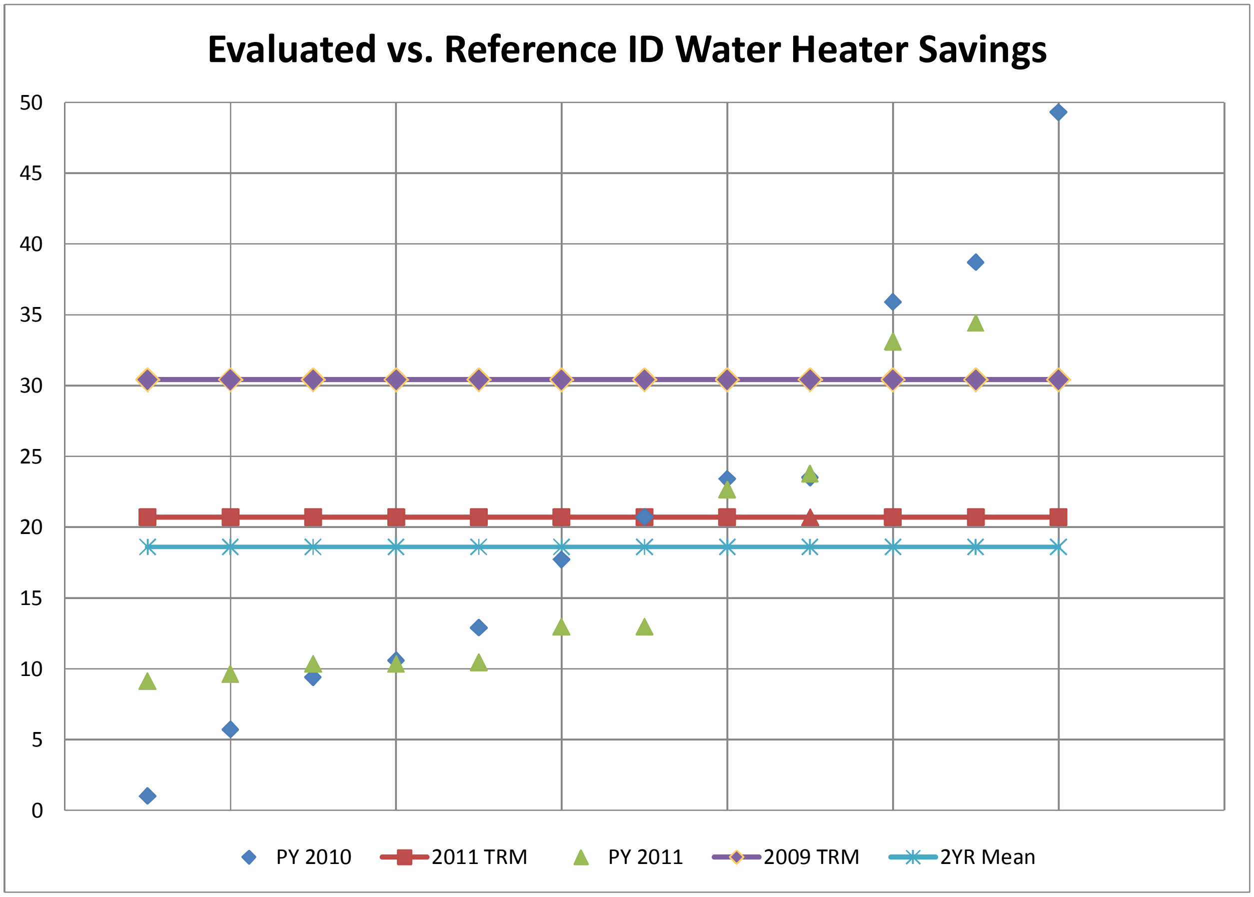
This section presents a comparison of the evaluated savings for indirect water heaters for program years 2010 and 2011. Table 20 provides a summary of the two-year evaluation findings for the savings and other key variables, which shows that generally the average savings and flow have dropped by about 17% and 38% respectively between the PY 2010 and PY 2011 evaluations.

Table 20: Consolidated Indirect Water Heater Findings – PY2010 & PY2011

Description	Counts		Savings		Flow (GPD)		Boiler Efficiency	
	2010	2011	2010	2011	2010	2011	2010	2011
Indirect Water Heater	12	11	20.7	17.2	532	330	90.0%	90.4%

Figure 20 provides a graphical presentation of the indirect water heater on-site savings data for PY 2011 and PY 2010 along with the 2009 TRM and 2011 TRM savings values and the two-year mean savings estimate. The two-year mean annual savings for the indirect water heaters is approximately 19.0 MMBtu/unit and provides an equally weighted combination of the evaluation results, which probably represents the best estimate of savings for the combined sample.

Figure 20: Evaluated Savings PY 2010 & PY 2011



5.7 Programmable Thermostats Findings

Thermostat type and temperature set point data were recorded for sites where the thermostats were accessible by the DNV KEMA on-site staff (primarily furnace and infrared heaters sites). When programmable thermostats were installed, the schedule and setback settings were recorded from the thermostat, for regular thermostats, customer reported schedule and setback settings were collected. Table 21 provides a summary of the comparison of the use of setback temperatures (top three data rows) as well the magnitude of the average setbacks.[14] The data shows that a large portion of the customers with regular thermostats (two-thirds) reported using temperature setbacks, while two of twelve with programmable thermostats did not use temperature setbacks. The average temperature setbacks (when used) were quite high for both groups with programmable thermostats being setback 8.6ºF and regular

[14] The average includes thermostats with zero setbacks and all of the data for the regular thermostat setbacks are customer reported values.

thermostats being setback 8.8ºF. The total average setback was 7.2ºF for all the programmable thermostats and 5.9 ºF for all regular thermostats, which is only a difference of 1.3 ºF based upon the customer reported settings.

Table 21: Programmable Thermostat vs. Regular Setback Comparison Customer Reported

Thermostat Type	No Setback	Yes Setback	Total	% No Setback
Programmable Thermostat	2	10	12	16.7%
Regular Thermostat	3	6	9	33.3%
Total	5	16	21	23.8%
Thermostat Type	**Avg. Deg F**	**Avg. Deg F**	**Total Avg. Deg F**	
Programmable Thermostat	0	8.6	7.2	
Regular Thermostat	0	8.8	5.9	
Grand Total	0	8.7	6.6	

Table 22 provides the same comparison of the programmable thermostats and the regular thermostats, but this time it is based on actual temperature data recorded near the thermostat. The data shows that the verified average temperature setback was actually greater than the customer reported values for the regular thermostats

Table 22: Programmable Thermostat vs. Regular Setback Verified Comparison

Thermostat Type	Verified Setback	Total	% No Setback
Programmable Thermostat	9	11	18.2%
Regular Thermostat	5	7	28.6%
Total	14	18	22.2%
Thermostat Type	**Verified Avg. Deg. F**	**Total Avg. Deg F**	
Programmable Thermostat	8.8	8.8	
Regular Thermostat	11.3	7.4	
Total	9.4	8.2	

DNV KEMA also conducted a literature review specifically to identify savings for C&I gas programmable thermostats and more generically any type of gas programmable thermostats. There were no recent studies identified for gas programmable thermostats either for C&I or residential applications that could be cited as reference to support altering the existing TRM savings values.

6. Next Steps

The good news is that the condensing boiler measure, which has been evaluated for three years, has achieved stable evaluation savings results that are highly correlated to the recommended deemed savings values. We recommend some minor adjustments to the deemed savings and see no further need to evaluate this measure. Since condensing boilers represent 75% of the program savings within this group of measures we would recommend that the sponsors not continue to conduct on-site impact evaluation on this group of measures. Although the on-site evaluation numbers for each of the remaining measures showed a significant variance from the current deemed values we would recommend that the sponsors accept the revised values based upon the two-year evaluation and focus their attention on other issues. These differences warrant the consideration of adjustments to the deemed savings values used for future measure installations. Additionally retroactive adjustments to unfiled savings may also be considered.

Below we provide recommendations for sponsor consideration based upon the observations from this study. However the sponsor decide to implement the recommended savings values from this evaluation they should make sure that each of the prescriptive measure savings are being applied consistently within the tracking system of each PA.

6.1 Condensing Boiler Recommendations

The savings for the condensing boiler measures are derived from three primary variables, the input capacity of the boiler, the measured efficiency of the boiler, and the operating hours - expressed as Equivalent Full Load Hours (EFLH). The capacity values were addressed as part of the 2011 KEMA evaluation of condensing boilers and the current savings recommendation includes those values. The mean measured efficiency observed in the PY 2010 evaluation sample (2012 study) was 88.9%, and the mean measured efficiency for the PY 2011 evaluation sample (2013 study) is 89.5%. The recommended efficiency value of 89.2% is calculated by pooling the values from the two studies based upon the error bounds.

The mean EFLH observed in the PY 2010 sample was 1,421 hours per year, and the mean EFLH observed in PY 2011 is 1,412 hours. There was some variation observed within the size categories, but most category level samples were small and there is no compelling reason to develop different EFLH values for the different categories. As a result, it is recommended that the EFLH value for the recommended savings calculation be changed to 1,416 hours for all size categories, which was calculated by pooling the values from the two studies.

Table 23 provides the savings variables and the recommended savings values, which should be incorporated into the TRM and used as measure savings values in the PA tracking systems. These recommended updates represent about a 3% increase in savings from last year's recommended values, which is a conservative adjustment given the evaluated relative performance of 107% for this measure. The recommended savings values from the Massachusetts Technical Reference Manual for Program Year 2011 – Report Version, August 2012 (Report 2011) shown in the last column for comparison.

Table 23: Condensing Boiler Savings Recommendations

Size Category	Capacity (MBtu)	Efficiency	EFLH	Recommended Prospective Savings (ΔMMBtu/Unit/yr)	PY 2011 MA TRM Savings (ΔMMBtu/Unit/yr)
Capacity ≤ 300 95% AFUE	150	92.1%	1416	**27.8**	NA
Capacity ≤ 300	209.6	89.2%	1416	**30.6**	29.8
300 < Capacity < 500	400	89.2%	1416	**58.4**	56.9
500 ≤ Capacity < 1000	735	89.2%	1416	**107.3**	104.6
1000 ≤ Capacity ≤ 1700	1350	89.2%	1416	**197.2**	192.1
1700 < Capacity	2363	89.2%	1416	**345.1**	336.2

The savings table also includes a recommended savings value for condensing boilers with an input capacity less than or equal to 300 MBtu and an Average Fuel Utilization Efficiency (AFUE) of 95% or greater. There were 104 of these 95% AFUE condensing boilers certified by the Air-Conditioning, Heating and Refrigeration Institute (AHRI) and the mean input capacity value was 127.5 MBtu. The capacity value of 150 MBtu was selected for the savings calculation because it represented the single most popular size option and was not unreasonably far from the mean. The Program Administrator's (PA's) should monitor the capacity of program participant boilers of this class and adjust this number as data becomes available.[15]

Table 24 provides a summary of the condensing boiler savings values through various "Planned" and "Report" versions of the MA TRM, which are defined as follows;

- Report 2010 = savings from the MA TRM 2010 Program Year – Plan Version August 2011
- Report 2011 = savings from the MA TRM 2011 Program Year – Report Version August 2012
- Report 2012 = KEMA recommended savings from this report

[15] The mean capacity value of the 104 AHRI certified boilers was 127.5 MBtu, only about 14% of those boilers had an input capacity of 210 MBtu or greater. There were a total of 13 boilers (12.5% of the total) with a capacity rating of 150 MBtu.

Table 24: Summary of Condensing Boiler Savings

Size	Efficiency Requirement	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
<= 300 MBH	>= 90% AFUE	22.1	29.8	**30.6**
301-499 MBH	>=90% Thermal Efficiency	42.3	56.9	**58.4**
500-999 MBH	>=90% Thermal Efficiency	77.1	104.6	**107.3**
1000-1700 MBH	>=90% Thermal Efficiency	142.6	192.1	**197.2**
1701+ MBH	>=90% Thermal Efficiency	249.0	336.2	**345.1**

6.2 Condensing Furnace Recommendations

The condensing furnace savings calculations utilize the same three primary savings variables as the condensing boilers, the input capacity of the furnace, the efficiency of the furnace, and the operating hours (expressed as EFLH).

The mean EFLH observed in the PY 2010 evaluation sample was 452 hours per year and the EFLH for the PY 2011 evaluation sample was 421 hours, based upon a sample of 12 and 10 furnaces respectively. Initially it was postulated that the warm temperatures during the 2012 study may have biased the results producing lower than expected operating hours, however the temperatures during the 2013 study were more normal and the average EFLH were actually reduced. Although secondary research indicated that the mean hours are lower than would typically be expected for commercial use there were several factors that contribute to the low operating hours observed in the sample as follows;

- Low operating hours of the facility or space served by the furnace,
- Furnace heating capacity is oversized for the space served,
- Additional heating sources already serving the space, and
- Use of programmable thermostats with aggressive setback settings.

Table 25 provides the recommended savings (Report 2012) for each furnace efficiency category, which represent about a 26% increase from the MA TRM PY 2011 savings values. The recommended savings values were developed from the mean savings values of the PY 2010 and PY 2011 sample sites.

Table 25: Recommended Condensing Furnace Savings

Furnace Efficiency	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
Furnace AFUE =>92%	21.1	5.9	**7.5**
Furnace AFUE =>92% w/ECM	19.6	5.5	**6.9**
Furnace AFUE =>94% w/ECM	23.6	6.2	**8.5**
Furnace AFUE =>95% w/ECM	NA	NA	**9.0**
Furnace AFUE =>96% w/ECM	NA	NA	**9.5**
Furnace AFUE =>97% w/ECM	NA	NA	**9.9**

Savings values were also calculated for three new condensing furnace efficiency categories as shown at the bottom of the table. These savings were calculated assuming that the mean input capacity for each would be 100 MBtu and that the EFLH would be 440 hours.[16]

6.3 Infrared Heater Recommendations

The Infrared Heater (IR Heater) savings calculation is somewhat similar to the previous heating measures except that the radiant nature of an IR Heater allows the unit to be sized smaller than a conventional warm air heater. The primary variable that impacts the IR Heater savings calculation is operating hours expressed as EFLH. The mean EFLH observed in the PY 2010 sample was 677 hours, which was significantly higher than the EFLH of 302 hours observed for the PY 2011 sample. The PY 2011 sample included buildings that were primarily using the IR heaters to keep products from freezing and set point temperatures were extremely low. The PY2010 sample also had buildings with similar heating applications, but it also contained buildings that used the heaters for space heating and the hours for those units were significantly higher than the mean. This technology has the potential to achieve significantly higher savings than has been observed in the PY 2011 sample, however implementing the measure through a prescriptive program has resulted in projects that only achieve marginal savings.

This measure has been evaluated for two years and all of the project savings have been significantly lower than the Report 2010 savings value of 74.4 MMBtu/unit. The Report 2011 savings of 22.3 MMBtu/unit is equal to the mean savings value from the KEMA Prescriptive Gas Final Program Evaluation Report, June 2012, which evaluated Program Year 2010 measures. The mean savings value from this year's study of PY 2011 measures was significantly lower at 7.2 MMBtu/unit. The two-year mean savings of 12.0 MMBtu/unit is the recommended savings for this measure as shown in last column of Table 26.

[16] The mean capacity for each of the higher efficiency categories was 80 to 86 MBtu so a mean program participant capacity value of 100 MBtu seems reasonable. Again the PA's could monitor this variable and make adjustments to the TRM as necessary.

Table 26: Recommended Infrared Heater Savings

Measure Type	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
Infrared Heater	74.4	22.3	**12.0**

This measure continues to be problematic from a post installation evaluation standpoint and further investigation into baseline conditions would be necessary to support modification of the savings values.

6.4 Indirect Water Heater Recommendations

The Indirect water heater savings is primarily a function of the amount of domestic hot water usage and as such, it is difficult to develop a prescriptive variable that would be predictive with respect to the amount of savings. The mean annual savings value observed in the PY 2010 on-site sample was 20.7 MMBtu/unit, and the mean savings value observed in the PY2011 on-site sample was 17.2 MMBtu/unit/yr. In both samples, there are large variations in the savings due to the water usage even though the mean savings for both samples was lower than the original annual savings of 30.4 MMBtu there were five sample sites that had savings that exceeded the original savings estimate (3 in PY 2010 and 2 in PY 2010).

The recommended savings value was using the simple average of savings results from the two studies and is 19.0 MMBtu/unit as shown in the last column of Table 27, which represents about an 8% reduction from the previous evaluation value (Report 2011).

Table 27: Recommended Indirect Water Heater Savings

Measure Type	Report 2010 Savings (MMBtu)	Report 2011 Savings (MMBtu)	Report 2012 Savings (MMBtu)
Indirect Water Heater	30.4	20.7	**19.0**

A. Appendix A - Condensing Boilers

A.1 Measure Description

Condensing boilers take advantage of improved design, sealed combustion, and condensing flue gasses in a second heat exchanger to increase efficiency. The flue gasses are then vented outdoors. The stack piping configuration also contains a separate inlet that draws combustion air from outdoors. This eliminates the use of interior space air for combustion and reduces infiltration into the building.

High efficiency boilers account for 440 projects with a total of 439,823 therms of annual savings in the Prescriptive Gas Tracking Data. Measurements were recorded and verification analyses were performed for 12 of these projects on 15 boilers. These projects have total annual savings of 25,791 therms. This is 5.9% of the total tracking savings for this measure.

Both the 2010 TRM and KEMA's analytic approach calculate the energy savings as a product of the hourly energy input times the annual hours of use times a factor representing the change in efficiency.

The 2010 TRM contains the following algorithm for calculating natural gas savings from these measures:

Equation 3: 2010 TRM Boiler Savings Calculation

$$\Delta\text{MMBtu} = (CAP)(EFLH_{heat})\left(\frac{\eta_{ee} - \eta_{base}}{\eta_{ee}}\right)$$

Where:

ΔMMBtu	=	gross annual MMBtu savings from the measure.
CAP	=	equipment heating capacity (MMBtu/h).
$EFLH_{heat}$	=	equivalent full load heating hours.
η_{ee}	=	installed equipment efficiency (expressed as a percentage).
η_{base}	=	baseline equipment efficiency (expressed as a percentage)

As shown in the savings equations, above there are three key variables that impact the savings for the condensing boiler, the capacity of the unit, the Equivalent Full Load Hours (EFLH) and the evaluated efficiency. Table 28 provides the assumed values for these variables that KEMA used to calculate the revised TRM savings values.

Table 28: Condensing Boiler TRM Savings Variable Values

Boiler Size Bin	Capacity	EFLH	$\acute{\eta}_{ee}$	$\acute{\eta}_{base}$
<= 300 MBH	165	1400	88.9%	80%
301-499 MBH	400	1400	88.9%	80%
500-999 MBH	750	1400	88.9%	80%
1000-1700 MBH	1350	1400	88.9%	80%
1701+ MBH	2363	1400	88.9%	80%

The PY 2011 TRM defines prescriptive savings based on five size strata. The values in the 2011 TRM are shown in Table 29 below.

Table 29: 2011 TRM Prescriptive Boiler Savings

Boiler Size/Efficiency	Savings (MMBtu/yr)
<=300 MBH - 90% AFUE or greater	29.8
301-499 MBH - 90% thermal efficiency or greater	56.9
500-999 MBH - 90% thermal efficiency or greater	104.6
1000-1700 MBH - 90% thermal efficiency or greater	192.1
1700+ MBH - 90% thermal efficiency or greater	336.2

A.2 Methodology

The energy savings from program-supported condensing boilers is the difference between the energy used by the boiler and the energy that would have been used by a boiler that would have been installed in the absence of the program. Since this difference cannot be directly observed, it is estimated based parameters that can. These include:

- The design specifications of the installed equipment
- The current to the combustion blower
- The temperature of the supply water from the boiler to the distribution system
- The temperature of the return water for the same system
- Meteorological data
- The reference baseline, assumed to be the least efficient equipment of comparable size legally available in the market place.

These parameters have been used in two previous evaluations for this measure, and have produced reasonable savings estimates.

In an effort to refine the analysis of these systems, with PA approval DNV KEMA incorporated two additional steady-state measurements into the onsite protocol for this year.

- Current to the boiler hydronic loop system pump - We postulated that pump motor current could be incorporated into the regression analysis to increase the accuracy of, and confidence in, the results. Due to the wide variation of pump configurations and control strategies found in the sample, the additional data did not add to the rigor of the analysis.
- Hydronic loop rate of flow. - DNV KEMA field staff attempted to use ultrasonic flow meters to measure the rate of hydronic loop flow. Two conditions must be met to enable measurement with this equipment. First, a minimum length of straight pipe of between five to twenty pipe diameters is necessary to determine reference flows. Second, the system must be calibrated absent any flows. These requirements were met in only a small subset of the sample and consequently the dataset for this measurement was not large enough to justify the additional complexity required for its inclusion in the analysis.

The data collected from these measurements was reviewed and served as a cross-check to the data collected by other means.

In addition to the steady-state measurements noted above, during the site visit, DNV KEMA technicians:

- Recorded the nameplate capacity and specifications of the equipment
- Measured steady-state combustion efficiency using hand-held meters in cases where the flue was accessible and the customer permitted measurement. This was possible at seven of the sample sites.
- Installed and confirmed operation of long term monitoring equipment noted below
- Recorded steady-state operating parameters measured by long term operating equipment
- Recorded, where possible, facility operating parameters and boiler control system settings.

For long-term monitoring, Onset Hobo® Micro station time-of-use loggers were installed to measure current to the combustion blower fan and the temperatures of the supply and return water at the boiler at one or five minute intervals. In addition to the parameters measured, the loggers also record the date and time stamp for each record. The field technician recorded the name-place capacity and model numbers of the installed equipment. The loggers were in place for between 44 and 88 days, with an average monitoring period of 75 days. The monitoring equipment at one site was retrieved after 44 days, earlier than planned, to accommodate an owner-initiated construction project.

After logger retrieval, the data was checked for consistency and completeness. The following steps were applied to the data for each site:

1. The Logger data were trimmed to remove any pre- and post-installation data that does not represent actual operating conditions.

2. The remaining data set was examined for anomalies, such as readings outside the expected range, and outliers were excluded from the analysis. The most frequent anomalies occurred in:

a. Combustion blower current draw – The maximum values recorded included spikes that far exceeded the steady-state operating parameters of the motors. These instantaneous readings captured the current draw on motor start up and do not correlate to boiler throughput. Inclusion of these values would greatly overstate the fuel throughput, so for this analysis the top five percent of values were excluded.

b. Convergence of supply and return temperatures – In some cases the supply and return temperatures converged over a several measurement intervals. These did not correlate to the time of day, normal facility operating parameters, or to meteorological data. Since there were several weather events during the monitoring period that may have resulted in electric power outages or facility closure, the data for these periods was adjusted to reflect normal operating conditions.

Two other data sets were required for the analysis, and both weather related. These were the average hourly temperature for the study period and the TMY data for four weather stations in Massachusetts, at Boston, Worcester, Millis, and Andover both expressed as outdoor dry bulb (ODB). This process resulted in clean and consistent sets of measured data incorporating the variables shown in Table 30 below.

Table 30: Measured Variables

Measured Variables (Study Period)		
Name	Measurement Interval	Source
Combustion Blower and Hot Water Pump Current (amperage)	1-minute	Data logger
Supply Water Temperature (^{0} F)	5-minute	Data logger
Return Water Temperature(^{0} F)	5-minute	Data logger
Study Period Outdoor Dry Bulb Air Temperature(^{0} F)	Hourly	NOAA
Typical Meteorological Year Outdoor Dry Bulb Temperature(^{0} F)	Hourly	TMY

The final piece of data used in the savings analysis was the monthly gas usage data for the site. For roughly half of the sample sites the billing data could be correlated to boiler input and for those sites, the engineering model was calibrated to actual usage. In other cases, billing data could not be correlated to boiler throughput primarily due to the presence of multiple end-uses on a single customer meter.

The analysis process began with the cleaned data sets.

Analysis Process Steps

The analysis for this year is based in SAS® statistical modeling instead of the spreadsheet model formerly used. SAS® has far superior regression analysis capability compared to spreadsheet software. This approach offers two benefits. First, SAS® offers superior analytic tools and data handling compared to spreadsheet-based models. Second, analysts can quickly check for correlation across wider ranges of variables, both in terms of count (how many individual variables are included in the analysis) and in terms of combinations (the number of variables that are compared to each other).

In this section, we provide a high-level overview of the steps in the analysis. While this accurately represents the logic of the analysis, in practice this is an iterative process that does not require a strict sequential order.

Step 1. The cleaned 1- and 5-minute interval data set is processed to develop average hourly combustion blower current draw and the average hourly supply and return water temperatures.

Step 2. The hourly data set is differentiated into two periods, weekdays (WD) and weekend/holiday (WEH) to accommodate typical control strategies.

Step 3. A boiler run time fraction is calculated for each hour in the sample. This factor is based on the current draw of each hour as compared to the average current draw of all time periods when the burner is operating.

The next series of steps expands the sample time frame measurements to the full year (8760 hours) and develops the factors necessary to calculate the usage difference between the installed and baseline equipment.

Step 4. Through an iterative series of regression analysis, coefficients are developed to calculate the boiler run time fraction, the supply temperature, and the return temperature for each hour based on the ODB temperature from typical meteorological year weather data. The objective of this analysis is to develop an equation that produces values for these three factors as close as possible to the observed measurements. These factors varied by site

Step 5. Using the equations developed in Step 4, the following are calculated for each hour of the year:

a. Boiler Run Time Fraction

b. Supply Water Temperature

c. Return Water Temperature

Step 6. Boiler performance coefficients are calculated based on secondary data. In the absence of specific data for the boiler installed at the monitored site, we used coefficients developed from representative boiler performance curves.

Step 7. The following hourly boiler operating variables are calculated based on the above:

d. Water Temperature Rise – The difference between the return water temperature and the supply water temperature, a function of heat input.

e. Pumping Heat Input – Calculated from estimated pump horsepower. Pumping contributes a small heat gain to the system which is captured in our analysis.

f. Boiler Power Output Fraction – Calculated as a function of the boiler run time and boiler return temperature, this factor captures the effects of modulating boilers.

g. Boiler Output – This is the calculated Btu output for the hour as a product of the steady-state output and the boiler power output fraction.

h. Boiler Efficiency - Hourly boiler operating efficiency is calculated as a factor of return water temperature and boiler run time fraction using the coefficients developed in Step 6 above.

i. Boiler Gas Input – A function of the installed gas input and the baseline boiler efficiency incorporating an adjustment for Btu added by pumping.

j. Baseline Gas Input – A function of the baseline efficiency for the equipment under consideration per the TRM, the weighted average annual efficiency calculated for the sample point, and the calculated boiler gas input.

At this phase in the analysis hourly factors for the full year have been developed. The next steps calculate the annual factors necessary to compare the measured savings to the tracked savings and to check the methodology and results.

Step 8. EFLH for the baseline and installed equipment are calculated based on the hourly boiler gas input and average efficiency.

Step 9. The average hourly inputs for the both the baseline and installed measure are calculated for the heating season based on the average efficiency and EFLH.

Step 10. Billing analysis, where appropriate, is used to calibrate the analysis outputs.

Step 11. The installed boiler gas input and baseline boiler gas input each are summed to develop the respective annual inputs. The difference between the two is ΔMMBtu, or the evaluated annual savings.

The on-site data analysis method utilized one-minute boiler combustion fan data that allowed for the measurement of boiler modulation effects. There was no need to add computational complexity to accommodate domestic water heating loads since they would be the same whether the boiler was efficient or baseline. Similarly, there was no need to accommodate heat loss from distribution system, or standby losses since they would be essentially equivalent regardless of boiler efficiency. There was no need to utilize different performance curves related to modulating firing rates, because the dew point of the flue gas is the same regardless of firing rate.

The use of TMY data to expand the on-site data was included to normalize the usage so that the results would represent more "typical" expected usage and savings.

A.3 Boiler Site Descriptions Summary

This section contains a brief overview of the sites included in the sample that had sufficient data to be carried forward into analysis.

Site ID #101 CB 1 – Residential multifamily apartment building

Tracked measures:

Quantity	Make	Model	Output Capacity
1	HTP	EL-22ON	203 MBTU

Building Characteristics/Site Data:
The subject building is a residential multifamily apartment building. Two boilers onsite for 12 one-bedroom apartment units and 12 two-bedroom apartments.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
6,000 sq. ft.	8'	Brick construction	Peaked roof

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 11, 2012 until March 1, 2013 for a total monitoring period of 79 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

There are two boilers onsite. Combustion analysis performed at time of installation on Boiler #1 % Eff. = 88.7%. The two boilers operate in a lead – lag configuration so the percent time on is lower for unit 2 since it appears to be the assigned lag boiler. Analysis shows lower percent time on, firing rate and calculated EFLH and for this reason.

Site ID #114_CB_4

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Raypak	H7-1505	1440 MBTU

Building Characteristics/Site Data:
The subject building is on the campus of a college. The building in which the condensing boilers were monitored is the Athletic Center. The facility includes; Indoor pool, Basketball Courts, Workout facilities, Locker rooms, offices, and meeting rooms. As the building serves as the college's recreational center, it is open year round except for holidays and at times in which it may close or reduce hours during semester breaks.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
46,514 sq. ft.	8'-35'	New Construction	Flat roof

Heating Schedule: Representative of scholastic schedule and varies during the year.

Logging Description:

The units described above were observed following the M&V plan from December 10, 2012 until March 7, 2013 for a total monitoring period of 86 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Combustion analysis was not possible due to lack of flue access. There is a third boiler which just does the pool load in the summer. There is a separate system for DHW.

Site ID #136_CB_4_22 – Four story residence hall

Tracked measures:

Quantity	Make	Model	Output Capacity
2	MACH	C-1050	1019 MBTU

Building Characteristics/Site Data:
Subject building is four-story residence hall on college campus. All brick, newly renovated construction with flat roof. Building height is 45 feet.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
	8’	All brick newly renovated construction	Flat roof

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.
Logging Description:

The units described above were observed following the M&V plan from December 13h, 2012 until March 8, 2013 for a total monitoring period of 84 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals. Pumps are three phase electric. DHW is a separate direct-fired gas system

Site ID #136_CB_4_60 – Four story residence hall

Tracked measures:

Quantity	Make	Model	Output Capacity
2	MACH	C-1050	1019 MBTU

Building Characteristics/Site Data:
Four-story residence hall.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
	8’	All brick newly renovated construction	Flat roof

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.
Logging Description:

The units described above were observed following the M&V plan from December 13, 2012 until March 8, 2013 for a total monitoring period of 84 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five-minute intervals. Pumps are three phase electric. DHW is a separate direct-fired gas system

Site ID #146_CB_2

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Burnham	ALP399F-2L07-399 CFH	377 MBTU

Building Characteristics/Site Data:
Senior Apartments, 106 units total. Two boilers on the site provide heating to individual buildings that have three living spaces.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
450 sq. ft. living spaces	8	Wood frame, R-15	R-30 Ceiling, peaked roof

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 3, 2012 until February 27, 2013 for a total monitoring period of 85 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Combustion Analysis spot test performed on site Efficiency = 87.9%. Important to note is these boilers work in parallel to a central plant which does a lot of the heating – so these boilers are supplemental. There is also a geothermal heating system operating at this facility.

Site ID #158_CB_1 -

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Burnham	Alpine ALP105w-2102	96 MBTU

Building Characteristics/Site Data:
The building is a commercial office with 1725 square footage.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
1725 sq. ft.	10 ft	Wood framed/R-11	Attic with pitched roof/R-30

Thermostat: Not determined
Heating Schedule:
Logging Description: Not determined

The units described above were observed following the M&V plan from December 12, 2012 until March 1, 2013 for a total monitoring period of 78 days. The boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals. The unit is condensing but there are observed periods where it operates in non-condensing mode based upon the return water temperature range. Spot combustion analysis yields 88.10% efficiency.

Site ID #165_CB_1 -

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Buderus	Logamax Plus GB162	255.2 MBTU

Building Characteristics/Site Data: Not determined

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
4820 sq. ft.	8'	Vinyl/masonry 50% each	Peaked roof-no attic

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 6, 2012 until February 26, 2013 for a total monitoring period of 81 days. The boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #176_CB_4 – Art Museum

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Lochinvar	SBN 1000	941 MBTU

Building Characteristics/Site Data:
Art Museum

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
Not determined	Not determined	Not determined	Not determined

Thermostat:
Heating Schedule: Not determined

Logging Description:

The units described above were observed following the M&V plan from December 14, 2012 until February 26, 2013 for a total monitoring period of 75 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #180_CB_4 – Large high-rise multifamily complex

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Hydrotherm	KN-10	927 MBTU

Building Characteristics/Site Data:
The subject building is a large high-rise multifamily complex. The complex is divided into sections or separate buildings interacting with a lobby, common area and health club. The two boiler system

provides heat to the building section which it serves and circulates heated water through two indirect hot water heaters.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
10,944 sq. ft.	8’	Brick masonry construction	Flat roof/R-Value Unknown

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 5, 2012 until March 4, 2013 for a total monitoring period of 89 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #180_CB_5 – High-rise multifamily complex

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Hydrotherm	KN-10	927 MBTU

Building Characteristics/Site Data:
The subject building is a large high-rise multifamily complex. The complex is divided into sections or separate buildings interacting with a lobby, common area and health club. The two boiler system provides heat to the building section which it serves and circulates heated water through two indirect hot water heaters.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
10,944 sq. ft.	8’	Brick masonry construction	Flat roof/R-Value Unknown

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 5, 2012 until March 4, 2013 for a total monitoring period of 89 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #201_CB_1 – Complex

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Weil-McLain	Ultra 155	139 MBTU

Building Characteristics/Site Data:

The subject building is a complex of five buildings associated with a religious charity which serve as temporary housing units for bible camps, charity workers, students, as a shelter and for other purposes. All buildings are older buildings and currently undergoing various stages of renovation. Building D is three-stories with brick faced 2x4 interior walls and a flat roof.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
3,072 sq. ft.	8'	Brick faced 2x4 Wood frame/R-11	Flat roof/R-Value Unknown

Thermostat: The system is zoned for individual thermostats on each floor.
Heating Schedule: Overall building heat is a combination of set-point adjustments by occupants on each floor.

Logging Description:

The units described above were observed following the M&V plan from December 10, 2012 until March 6, 2013 for a total monitoring period of 85 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #201_CB_1 – Complex

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Weil-McLain	Ultra 155	139 MBTU

Building Characteristics/Site Data:
As above - Building E is three-stories with brick faced 2x4 interior walls and a flat roof.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
3,072 sq. ft.	8'	Brick faced 2x4 Wood frame/R-11	Flat roof/R-Value Unknown

Thermostat: The system is zoned for individual thermostats on each floor.
Heating Schedule: Overall building heat is a combination of set-point adjustments by occupants on each floor.

Logging Description:

The units described above were observed following the M&V plan from December 10, 2012 until March 6, 2013 for a total monitoring period of 85 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #224_CB_2 -

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Viessman	Vitodens 200w	274 MBTU

Building Characteristics/Site Data:

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
Not determined	Not determined	Not determined	Not determined

Thermostat: Not determined
Schedule:

Logging Description:

The units described above were observed following the M&V plan from December 6, 2012 until February 27, 2013 for a total monitoring period of 82 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #224_CB – Three-story multifamily housing

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Lochinvar	KBN-800	752 MBTU

Building Characteristics/Site Data:
The subject building is a large three-story multifamily housing building which is interconnected on either end by similar large multifamily family buildings. In all, these buildings comprise a large subsidized housing renovation project; completed in 2010. There are 31 units in the building of varying sizes. The building is brick faced, with interior walls rebuilt with 2x6 construction. The flat roof has a cavity insulated with cellulose. A three boiler staged system provides heat to the building and circulates heated water through two 120 gallon indirect hot water heaters.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
11,460 sq. ft.	8'	Brick faced 2x6 Wood framing/R-19	Flat roof/R-30

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 6, 2012 until March 5, 2012 for a total monitoring period of 88 days. Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #224_CB_2 – Three story free standing building

Tracked measures:

Quantity	Make	Model	Output Capacity
1	KBN-800	Lochinvar	752 MBTU

Building Characteristics/Site Data:
The subject building is a three-story free standing building comprised of six small one-bedroom apartments. The original building construction is old, but has been recently renovated both inside and out. Interior walls have been fully insulated and new vinyl siding with insulation board underlayment adds to the insulation value. A flat roof cavity is blown with cellulose insulation. One boiler system provides heat to the building and circulates heated water through an indirect hot water heater.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
5,616 sq. ft.	8’	Wood framed/R-15	Flat Roof/R-30

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 6, 2012 until March 5, 2012 for a total monitoring period of 88 days. The boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

B. Condensing Furnace

B.1 Condensing Furnace Measure Description

This projected evaluated the performance of high efficiency natural gas warm air furnace both with and without an electronically commutated motor (ECM) for the fan. High efficiency furnaces are better at converting fuel into direct heat and better insulated to reduce heat loss. These furnaces achieve higher efficiency by sending flue gasses through a secondary heat exchanger that extracts heat from the exhaust gasses. The flue gasses are then vented outdoors. The stack piping configuration also contains a separate inlet that draws combustion air from outdoors. This eliminates the use of interior space air for combustion and reduces infiltration into the building.

High efficiency warm air furnaces account for 230 projects with a total of 62,193 therms of savings in the Prescriptive Gas Tracking Data. Measurements were recorded and verification analyses were performed for 10 of these projects. These 10 projects have total annual savings of 892.24 therms. This is 1.43% of the total tracking savings for this measure.

The 2011 TRM report version defines prescriptive savings based on three efficiency strata. The values for the PY2011 TRM are shown in Table 31 below.

Table 31: 2011 TRM Prescriptive Furnace Savings

Furnace Efficiency	ΔMMBTU/Unit/yr
Furnace AFUE = >92%	5.9
Furnace AFUE = >92% w/ECM	5.5
Furnace AFUE = >94% w/ECM	6.2

B.2 Condensing Furnace Methodology

Onset Hobo Micro Station time-of-use loggers were installed that measured the current of the air handler motor at one minute intervals and the temperature of the supply and return air at the furnace at five minute intervals. Additionally where the conditioned space was accessible data, loggers were installed at the controlling thermostat to record the temperature of the conditioned space heated by the furnace. The loggers were in place for between 42 and 77 days, with an average monitoring period of 68 days.

After logger retrieval the data was checked for consistency and completeness, the following steps were applied to the data for each measure:

1. The Logger data was trimmed to remove any pre- and post-installation data that does not represent actual operating conditions.

2. The remaining data set was examined for anomalies, such as readings outside the expected range. For example, the current draw by the air handler motor was recorded in a small number of 5-minute intervals during the start-up phase. In these cases, which occurred for less than a fraction of one percent of the readings, the recorded data point exceeds the average by a factor of approximately five. Since this was an instantaneous reading, and not representative of the 5-minute interval, using this data point in subsequent analyses would skew the results. Consequently, these data points were replaced with the average of the data set absent the outliers.

Two other data sets were required for the analysis, and both weather related. These were the average hourly temperature for the study period and the TMY data was for four weather stations in Massachusetts, at Boston, Worcester, Chicopee Falls, and Pittsfield. This process resulted in clean and consistent sets of measured data incorporating the variables shown in Table 32 below.

Table 32: Measured Furnace Variables

Variables (Study Period)		
Name	Measurement /Input Interval	Source
Air Handler Motor Current (amperage)	1-minute	Data logger
Supply Air Temperature at Furnace (^{o} F)	5-minute	Data logger
Return Air Temperature at Furnace (^{o} F)	5-minute	Data logger
Temperature of Conditioned Space at Thermostat	5-minute	Data logger
Study Period Outdoor Dry Bulb Air Temperature (^{o} F)	Hourly	NOAA
Typical Meteorological Year Outdoor Dry Bulb Temp. (^{o} F)	Hourly	TMY

Analysis Process Steps

In this section, we provide a high-level overview of the steps in the analysis. While this accurately represents the logic of the analysis, in practice this is an iterative process that is not conducive to strict sequential presentation.

Step 1. The 1-minute current and 5-minute temperature interval data is first processed for errors by the SAS® statistical software package.

Step 2. Hourly profiles of air handler motor current and average hourly supply and return air temperatures.

Step 3. The hourly data set is differentiated into two periods, weekdays (WD) and weekend/holiday (WEH) to accommodate typical control strategies.

Step 4. A furnace power output fraction is calculated for each hour in the sample. This factor is based on the current draw of each hour as compared to the maximum current draw of all time periods when the burner is operating.

The next series of steps expands the sample time frame measurements to the full year (8760 hours) and develops the factors necessary to calculate the usage difference between the installed and baseline equipment.

Step 5. Through an iterative series of regression analysis, coefficients are developed to calculate the burner run time fraction, the furnace output fraction, the supply temperature, and the return temperature for each hour based on the outdoor dry bulb (ODB) temperature from typical meteorological year weather data. The objective of this analysis is to develop an equation that produces values for these factors as close as possible to the observed measurements. These factors will vary for each site.

Step 6. A factor for heat added from air circulation, including the blower motor waste heat is calculated for each system.

Step 7. Using the equations developed in Step 4, the following are calculated for each hour of the year:

a. Furnace Run Time Fraction

b. Furnace Output Fraction

c. Supply Air Temperature

d. Return Air Temperature

Step 8. Furnace performance coefficients are calculated based on secondary data. In the absence of specific data for the furnace installed at the monitored site, we used coefficients developed from representative furnace performance curves.

Step 9. The following hourly boiler operating variables are calculated based on the above:

a. Furnace Output – This is the calculated Btu output for the hour as a product of the steady-state output and the furnace power output fraction.

b. Furnace Efficiency - Hourly furnace operating efficiency is calculated as a factor of supply air temperature, furnace run time fraction, and furnace output fraction using the coefficients developed in Step 4 above.

c. Furnace Gas Input – A function of the installed gas input and the baseline furnace efficiency incorporating an adjustment for Btu added by circulation.

d. Baseline Supply Air Temperature – A function of the calculated hourly return air temperature of the operating unit.

e. Baseline Furnace Efficiency – A function of the calculated run time and output fractions of the measured unit, the baseline efficiency contained in the TRM, and the baseline supply air temperature.

f. Baseline Gas Input – A function of the baseline efficiency for the equipment under consideration per the TRM, the weighted average annual efficiency calculated for the sample point, and the calculated furnace gas input.

At this phase in the analysis hourly factors for the full 8760 hours of the year have been developed. The analysis also uses the 8760 hour expansion model for each site to develop equivalent full load hours and the calculated efficiency for each unit. The baseline furnace assumption was a non-condensing furnace operating at maximum of 80% at optimum and slightly less efficiency at lower output fractions (78%).

Step 10. The installed furnace gas input and baseline furnace gas input each are summed to develop the respective annual inputs. The difference between the two is ΔMMBtu, or the evaluated annual savings.

B.3 Furnace Site Descriptions

Site ID #117_FU_3 – Commercial freestanding building

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Carrier	58UVB080-14	**100 MBTU**

Building Characteristics/Site Data:
The subject building is a commercial freestanding building housing a pediatric doctors' practice. It has two stories, with the second story covering about half the area of the first floor. The area of the monitored furnace is half of the lower level and included the waiting room and parts of the main office area.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
1,104 sq. ft.	8'	Wood framed 2x6/R-19	Heated 2nd floor above

Thermostat: A wall mounted programmable thermostat is located in a hallway near the office area.
Heating Schedule: Set office hours are programmed; M,W,F 8am-5pm at 70 degrees F, Tu, Th, 8am-8pm at 70 degrees, Sat 8am-2pm at 70 degrees F, Set-back to 60 degrees F at night and when closed Sunday and holidays.
Logging Description:
The unit described above was observed following the M&V plan from December 13, 2012 until February 22, 2013 for a total of monitoring period of 70 days. One logger was set to monitor air handler motor

amps, as well as ones for the supply and return air temperatures. An additional data logger monitored the temperature near the thermostats. Loggers were set to record at one minute and five minute intervals respectively. Spot test with combustion analyzer yielded 96.6% combustion efficiency.

Site #126_FU_3 – Commercial Strip Mall

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Goodman	GMVG961155DXAB	109 MBTU

Building Characteristics/Site Data:

The subject building is a commercial strip mall with 7-8 businesses. This is a restaurant that occupies the right end unit of this building. The business is split down the middle between the kitchen/take out counter and customer waiting area on one side and a full bar and table seating on the other. Residual heat from the pizza ovens and cooking stoves limits the need for direct heat in the kitchen area.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
3,000 sq. ft.	14'	Brick faced 2x4 walls/R-11	Flat roof/R-Value unknown

Thermostat: A programmable wall mounted thermostat controls the furnace unit and is located on the back wall of the seating section, away from the kitchen. **Heating Schedule:** Thermostat programming follows business hours: M-Su; 10am-12am, set at 65 degrees F, Overnight; Midnight-10am set back to 55 degree F.

Logging Description:

The unit described above was observed following the M&V plan from December 20, 2012 until March 7, 2013 for a total of monitoring period of 76 days. One logger was set to monitor air handler motor amps, as well as ones for the supply and return air temperatures. An additional data logger monitored the temperature near the thermostats. Loggers were set to record at one minute and five minute intervals respectively.

The equipment had relatively low percent time on and firing rates which could be explained by the fact that the large cooking ovens are providing the majority of the heating for the conditioned space in the dining area of this restaurant.

Site ID #138_FU_2 – House of Worship

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Goodman	GCVC91155DX	109 MBTU

Building Characteristics/Site Data:

The subject building is a house of worship originally built in 1913. The building is a wood framed stand-alone structure with high ceilings and large windows. The walls are the original lathe and plaster and suggest few building renovations have taken place. One exception is new blown cellulose insulation in the flat roof cavity offered through one of the Energy Efficiency Programs. The two condensing furnace replacements are situated in small utility rooms located just inside the worship area on both the right and left exterior walls. Distribution is limited with ductwork from the Air Handler Units going to large vents toward the top of the utility room and smaller return vents near the floor.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
2,400 sq. ft.	30’	Wood framed/No R-Value	Flat roof/R-45 Cellulose

Thermostat: Wall mounted standard manual thermostats operate each furnace unit. **Heating Schedule:** Sat; 8:30-11:30, during other times of worship, and for other occasions the thermostats are set at 68 degrees F. All other times they are left at 60 degrees F.

Logging Description:
The units described above were observed following the M&V plan from December 4, 2012 until February 20, 2013 for a total of monitoring period of 77 days. One logger was set to monitor air handler motor amps, as well as ones for the supply and return air temperatures for each furnace unit. An additional data logger monitored the temperature near the thermostats. Loggers were set to record at one minute and five minute intervals respective

Regular occupancy of the building occurs only on weekends. The two subject furnaces provide supplemental heat to the congregation area only. The entire building has a central heating system that operates as the primary source of space heating. Data files show very small percent time on and minimal firing rates resulting in small calculated savings.

Site ID # 178_FU_2 – Large Commercial Building

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Trane	TUHIB040A9241AA	40 MTBU

Building Characteristics/Site Data:
The subject building is a large commercial building comprised of a small front office area and a large garage work area in the rear. The condensing furnace unit replaced a small unit which heats only the office area. The building is constructed with metal paneling but the office area has 2x4 finished walls on the interior, and a drop ceiling which is insulated behind.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
756 sq. ft.	8’	2x4 Wood framed/R-11	Ceiling/R-13 Insulation

Thermostat: The unit is controlled by a wall mounted programmable thermostat located in the owner’s office of the office area. **Heating Schedule:** Programmable schedule is strictly in place: M-F; 5:30am-8:30am, set at 65 degrees F, 8:30am-3:30pm set at 70 degrees F, 3:30pm-6:00pm set at 60 degrees F. Overnight, Sat, Sun and Holidays set-back to 58 degrees F.
Logging Description:
The unit described above was observed following the M&V plan from December 12, 2012 until February 21, 2013 for a total of monitoring period of 70 days. One logger was set to monitor air handler motor amps, as well as ones for the supply and return air temperatures. An additional data logger monitored the temperature near the thermostat. Loggers were set to record at one minute and five minute intervals respectively.

The subject furnace provides space heat for an office area conditioned space only; the rest of the facility heat is supplied by central heating system that is fueled by waste oil. Site interviews indicate that only the business owner controls the thermostat which controls the subject furnace. Conditioned space temperatures of this office area are low which suggests small savings.

Site ID #209_FU_2 – Club house, dining and banquet facilities

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Carrier	58MVC060-14	120 MTBU

Building Characteristics/Site Data:
The subject buildings are the clubhouse, dining, and banquet facilities operated by a country club type of business. The new condensing furnace is just one of several furnace systems serving this facility. This unit is zoned for the front dining area which gets normal daily use and includes a back kitchen area and some hallway area as well. This dining area is used on a regular basis. Overall, the building is newer construction and well built.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
2,688 sq. ft.	8'	Wood framed 2x6/R-19	Heated area above

Thermostat: The condensing furnace is controlled by a wall mounted programmable thermostat that is positioned on an interior wall near to where the heating zones overlap in the dining area. **Heating Schedule:** Facility closes each year during the month of February. Programmable thermostat is set for normal set-up and business hours. M-Sun; 7am-10am set to 65 degrees F, 10am-10pm set to 70 degrees F, 10pm overnight set-back to7am at 60 degrees F. Facility is open most holidays throughout the year and may only be closed during the February shut-down.

Logging Description:

The unit described above was observed following the M&V plan from December 20, 2012 until March 7, 2013 for a total of monitoring period of 76 days. One logger was set to monitor air handler motor amps, as well as ones for the supply and return air temperatures. An additional data logger monitored the temperature near the thermostat. Loggers were set to record at one minute and five minute intervals respectively.

The new condensing furnace is just one of several furnace systems serving this facility. Other furnaces provide heat to other zones. The location of the subject thermostat is positioned in an area of heating zone overlap in the dining room. Facility was closed in February during the monitoring period.

Site ID #221_FU_1 – House of worship

Tracked measures:

Quantity	Make	Model	Output Capacity
1	American Standard	AUC1D120A9601AD	113 MTBU

Building Characteristics/Site Data:
The subject building is a large old church with attached administrative offices and other space. The new condensing furnace provides heat to an area directly under the church's worship area that is used for children's Sunday school. This area is comprised of three individual classrooms and an adjoining hallway along with some inaccessible storage areas. The building is made of brick with finished interior walls.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
1920 sq. ft.	8'	Wood framed 2x4/R-11	Heated floor above

Thermostat: There are two wall mounted Thermostats, one in each of the two large classrooms. One is programmable while the other is standard. **Heating Schedule:** Both thermostats are manually set to 70 degrees during weekend classroom activity and set-back to 60 degrees when the rooms are not in use the rest of the week.

Logging Description:

The unit described above was observed following the M&V plan from December 11, 2012 until February 20, 2013 for a total of monitoring period of 71 days. One logger was set to monitor air handler motor amps, as well as ones for the supply and return air temperatures. Two additional data loggers monitored the temperature near the thermostats. Loggers were set to record at one minute and five minute intervals respectively.

The subject furnace is one of three new modular condensing furnaces that provide supplemental heat to conditioned spaces that are also heated by a separate central heating system. This subject unit appeared to cycle on far more often than the other units which may suggest it is providing overlap heating to other zones. Spot combustion analysis was performed at the time of data logger retrieval in two different modulation levels, mid-fire was 92.1% combustion efficiency and hi-fire was 97.5% combustion efficiency. However, the unit was not observed to operate on hi-fire during normal operation when controlled by the thermostat.

Site ID #248_FU_2 – Pre-school/Grammar school

Tracked measures:

Quantity	Make	Model	Output Capacity
2	York	TG9S100C16MP11A	95 MTBU

Building Characteristics/Site Data:

The subject building is a privately run preschool/grammar school**.** The school is more or less in the shape of a small "t" with a main hallway ending in a cafeteria room and with a four-classroom wing on each side. New condensing furnaces were installed in each of the classroom wings. There are a total of four furnace systems for the entire school. The building is a 1970's era wood framed building with 2x 4 construction but has had additional insulation added to the attic.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
1,600 sq. ft.	8'	Wood framed/R-11	Attic with pitched roof/R-30

Thermostat: The left wing had a programmable thermostat which was taken down because it was not working properly. It now has a standard wall mounted thermostat. **Heating Schedule:** Heating schedule follows school schedule: M-F 6am-8am, set to 65 degrees F, 8am-3pm, set to 68-70 degrees F, 3pm-6pm set to 60-65 degrees F. Weekends, Holidays, Vacations and overnight set-back to 60 degrees F.

Logging Description:

The unit described above was observed following the M&V plan from December 12, 2012 until February 21, 2013 for a total of monitoring period of 70 days. One logger was set to monitor air handler motor amps, as well as ones for the supply and return air temperatures. An additional data logger monitored the temperature near the thermostat. Loggers were set to record at one minute and five minute intervals respectively.

Subject unit is one of four modular units providing heat to each of four wings of school. Occupancy is primarily weekday only.

Site ID #250_FU_3 – Free standing commercial building

Tracked measures:

Quantity	Make	Model	Output Capacity
1	Rheem	HQ5D701P01101741	97 MTBU

Building Characteristics/Site Data:
The subject building is a free standing commercial building with an auto parts storefront and a large attached warehouse space in the rear. The new condensing furnace services this warehouse space. Wall construction is brick on the outside and block on the inside with presumably no insulation value. The ceiling of this warehouse is a suspended tile ceiling with fiberglass batting.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
2,464 sq. ft.	15’	Brick & Block/No R-Value	Flat roof, drop ceiling/R-19

Thermostat: Programmable thermostat is wall mounted on an interior wall.
Heating Schedule: Programming schedule set to store hours: M-Sat; 8am-5pm, set at 68 degrees F, Sun, Holidays and overnight; set-back to 55 degrees F.
Logging Description:
The unit described above was observed following the M&V plan from December 14, 2012 until February 27, 2013 for a total of monitoring period of 74 days. One logger was set to monitor air handler motor amps, as well as ones for the supply and return air temperatures. An additional data logger monitored the temperature near the thermostat. Loggers were set to record at one minute and five minute intervals respectively.

The subject unit replaced an older vintage furnace in the back of the building which is a parts warehouse. Employees were observed to wear heavy clothing as they work in and out of a loading delivery area with large overhead doors. The data reflected low temperatures within the conditioned space and low percentage operating time.

C. Infrared Heaters

C.1 Infrared Heaters Measure Description

This project evaluated the performance of gas-fired low intensity infrared heating systems installed in place of unit heater, furnace, or other standard efficiency equipment. Low-intensity heaters have an enclosed flame. When heat is required, the burner control box ignites a gas/air mixture and hot gases are pushed through steel radiant tubing by an internal fan. As these gases pass through the assembly, the tubing is heated and emits infrared energy, which is then directed toward the floor by highly polished reflectors. This energy is absorbed by objects in its path, such as the floor, machinery, and people. Objects in the path of the infrared energy in turn re-radiate this heat to create a comfort zone at the floor level.

Infrared-heating accounts for 33 projects with a total of 78,120 therms of savings in the Prescriptive Gas Tracking Data. Measurement and verification analyses were performed on 11 of these projects. These 11 projects have total annual savings of 797.3 therms. This is 1.02% of the total tracking savings for this measure.

The 2010, 2011 and 2012 versions of the Massachusetts TRMs have a fixed savings per installed unit. The value shown for the 2012 TRM is 48.3 MMBtu/year. The value shown for the 2010 TRM is 77.4 MMBtu/year while the value shown in the 2011 TRM is 74.4 MMBtu/year.

C.2 Methodology

The energy savings from program-supported infrared heaters is the difference between the energy used by the infrared heater and the energy that would have been used by a conventional unit heater that would have been installed in the absence of the program. Since this difference cannot be directly observed, it is estimated based on parameters that can. These include:

- The design specifications of the installed equipment.
- The current to the combustion blower (radiant burner combustion blower motor current).
- The temperature set point and room temperature of the conditioned space measured in close proximity to the thermostat that controls the subject infrared heater.
- The room temperature of the conditioned space measured at five (T-low), ten (T-mid) and fifteen (T-high) foot height intervals, if the space is sufficiently tall. A variety of conditioned spaces for the sample sites generated slight variations but all sites ended up with two to four room temperature data files.
- The distance of the infrared heater above the floor.

- Meteorological data
- The reference baseline, which is assumed to be a unit heater with equivalent output capacity operating at 80% combustion efficiency.

Hobo Micro-Station® time of use data loggers were used to record operating parameters at of the infrared equipment at one minute intervals. Additional data loggers were installed to measure temperatures within the conditioned space that served by IR heaters if not precluded by the nature of operations and/or the facility. The loggers were in place for between 75 and 82 days, with an average monitoring period of 77 days.

After logger retrieval, the data was checked for consistency and completeness. The data set then was examined for anomalies, such as readings outside the expected range, and corrected. For example if the space temperature reading exceeded the reasonable range or the current inrush was captured by the logger, these data points are corrected to fall within a reasonable range.

In addition to the site-collected data, the analysis required the measured hourly temperatures and typical meteorological year data for weather stations in Massachusetts, at Boston, Worcester, Millis, and Andover. The variables for the analysis are shown in Table 33.

Table 33: Infrared Heater Variables

Variables (Study Period)		
Name	Measurement /Input Interval	Source
Combustion blower Current (amperage)	1-minute	Data logger
Conditioned Space Temperatures	1-minute	Data logger
Thermostat Set Point and Room Temperature	Install/Retrieval	On site
Study Period Outdoor Dry Bulb Air Temperature (^{0} F)	Hourly	NOAA
Typical Meteorological Year Outdoor Dry Bulb Temp. (^{0} F)	Hourly	TMY

Analysis Process Steps

In this section, we provide a high-level overview of the steps in the analysis. While this accurately represents the logic of the analysis, in practice this is an iterative process that does not require a strict sequential order.

Step 1. The following factors are developed from the cleaned 1-minute interval data set:

a. Maximum burner blower current draw throughout the monitoring period. In select cases, maximum values were reduced by a factor 5% to filter out impedance spikes of fan start cycles.

b. Thermostat set point and close proximity room temperatures.

c. Low-, mid-, high- height inside conditioned space temperatures.

Step 2. The 1-minute interval data for the factors above are processed within a SAS® statistical model to develop hourly averages across the monitoring period for the following:

a. Percent time on, the fraction of the hour the equipment is actively firing,

b. Current draw,

c. The hourly firing rate is calculated based on the current draw and percent time on.

d. Temperature as measured at the room thermostat,

e. IR heater output in Btu/hr is calculated based on the percent time on, firing rate and rated capacity.

f. Temperature rise, representing the degree of temperature stratification within the conditioned space. It is typically T-high minus T-low as measured when the infrared unit is not firing.

Step 3. Additional variables such as the nameplate rated heating capacity and mounting height, and the thermostat temperature set point which are specific to each site are used to calculate hourly IR output.

Step 4. The IR heater hourly output is the product of the hourly firing rate, the hourly percent time on and the hourly average percent time on.

Step 5. The hourly data set is differentiated into two periods, weekdays (WD) and weekend/holiday (WEH) to accommodate typical control strategies.

Step 6. Coefficients for the independent variables of hour of the day and outdoor temperature, differentiated by weekday and weekend/holiday, are developed to provide the best fit between the hourly firing rate, IR heater hourly output and hourly percent time on using these coefficients and the values derived from the monitoring data.

Step 7. The final step expands the sample time frame measurements to the full year (8760 hours) and develops the factors necessary to calculate the usage difference between the installed and baseline equipment. These coefficients are used to generate the Btu/hr value inputs required for both IR heater and the baseline across the full year. For this set of calculations, the space heating equipment was forced off when the outdoor temperature exceeded a calibrated, site-specific threshold temperature.

a. IR Compensating Factor – Manufacturers' sizing recommendations incorporate a compensating factor for IR heating equipment based on the difference in heat output required to heat objects by radiation as compared heating the ambient air and the objects within the envelope by convection.[17] This factor is directly related to the mounting height of heater.

Table 34: IR Compensating Factors

Mounting Height	IR Compensating Factor
12	0.78
16	0.80
20	0.82
24	0.84
28	0.86
32	0.88
36	0.90
40	0.92

a. Thermal efficiency of the IR heater – The thermal efficiency of the IR heater was calculated by an engineering analysis of the physical properties of atmospheric natural gas combustion, the theoretical minimum and maximum temperatures at which a low intensity heater fire tube would radiate heat, and other factors. Based on this analysis 82% thermal efficiency was used in calculations.

b. The baseline equipment for all analyses was modeled as a suspended unit heater with thermal efficiency of 80% serving the equivalent area as the site IR heaters. The output of the unit heater is sufficient to meet the same building heat requirement as the IR heater(s) monitored.

Table 35 below illustrates the comparison of these factors, and how they relate to building heat requirements.

Table 35: Sample Calculation of IR vs. Unit Heater Sizing

Sample Calculation		
	IR Htr	Unit Htr
ASHRAE building heat load	100,000	100,000
Compensation factor	0.850	1.000
Output heat Required	85,000	100,000
Thermal Efficiency	82.0%	80.0%
Input heat Required	103,659	125,000

Step 8. The hourly Btu inputs for the IR heater(s) and baseline are summed across the year and the difference between the two is the annual savings, expressed in MMBtu based upon the following equations:

[17] Ibid.

Hourly gas savings = Hourly gas input (consumption of baseline – consumption of subject unit)

Hourly gas savings = (Baseline Unit heater hourly output)/ Compensation Factor - (IR heater hourly output)

Annual gas savings = Sum of Hourly gas savings

EFLH = Sum of 8670 (hourly firing rate) x (hourly percent time on) values.

Step 9. Billing analysis is then used to check the analysis outputs, specifically the calculated gas savings value.

Step 10. Calculation of Alternate Infrared Savings Factor.

SAS® statistical modeling created 8760 hourly annual operating profiles for the 11 infrared heater sample sites. With this information, additional analysis done on the relationship between infrared heating and conventional unit heater gas use.

Specifically, the following hourly parameters were analyzed:

(Temperature Gradient): the difference between average inside temperature and outside temperature. Simply stated the potential for savings is directly proportional to the amount of heat required for the conditioned space. Either thermostat set point or the difference between average internal and external temperatures can be used as a rough estimation to the amount of heating being done. For example, one of the sites with a small calculated savings value had a thermostat set point of 45° F which helps to explain the relatively small savings.

(Temperature Rise): the difference between internal temperatures which typically is the ceiling temperature less the floor temperature. This represents the amount of temperature stratification in the conditioned space.

(Thermostat Set Point): Thermostat set points determine the call-for-heat in the conditioned space.

(Firing Rate): The hourly average percent of maximum rated output when unit was on.

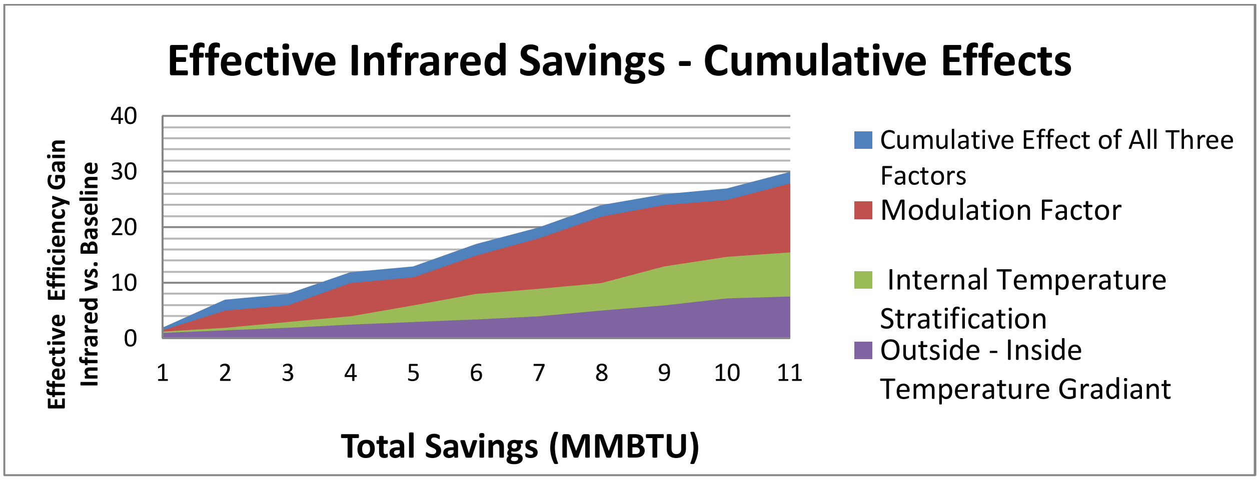
(Percent Time On): The hourly average fraction the unit actively operated.

Based on our analysis, we determined that there may be an additive gas saving from the difference in performance between IR and unit heaters on three indices:

- the amount of heating being delivered by the equipment
- the amount of temperature stratification that is present in the conditioned space
- the amount of time the equipment operates.

Figure 21 Figure 21shows the cumulative effect of three factors on the potential savings that may be possible with the use of infrared heating equipment versus conventional unit heating.

Figure 21: Effective Infrared Savings Cumulated Effect



The effective efficiency gain from the use of infrared heaters is a function of the cumulative effects of the difference between the indoor and outdoor temperatures, the degree of thermal stratification within the conditioned space, and the modulation of the equipment.

Table 36Table 35 uses the expanded 8760 hour model data of each of the 11 sites in the infrared sample to illustrate the potential contribution to savings that the three factors can have individually and combined.

Table 36: Potential Contributions to Savings of IR vs. Conventional Unit Heater

Effective Infrared Savings	Charactorization of :	Effective Efficiency Gain, (additive %)
Amount of Heating		
function (Inside – Outside Temperature Gradient)	Average Tstat -ODB = 0-10° F	1%
	Average Tstat -ODB = 10 - 25° F	5%
	Average Tstat -ODB = > 25 ° F	10%
Amount of Temperature Stratification		
function (Temperature Stratification Conditioned Space)	Internal Temp Difference = 0-3° F	0%
	Internal Temp Difference = 3-10° F	4%
	Internal Temp Difference = > 10° F	8%
Duration of Time the Equipment Operates		
function (Modulation Factor of Equipment)	Modulation Factor = 0-2%	2%
	Modulation Factor = 2-10%	5%
	Modulation Factor = >10%	12%
Combination of all Three Factors		**Probable Range of 2 - 30%**

C.3 Infrared Heaters Site Descriptions

Site ID #108_IR_2 – Commercial free standing building

Tracked measures:

Quantity	Make	Model	Output Capacity
8	Space Ray	LTU 125-40	125 MBTU

Building Characteristics/Site Data:
The subject building is a commercial free standing building. A large manufacturing area comprises most of the building with office and meeting space in the front. Building was built in 1968. There are two 12'x14' overhead doors in a loading dock area which are open 5-6 times a day for only about 10 minutes each time.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
40,000 sq. ft.	28'	Metal paneling/No insulation	Metal roof/No apparent insulation

Thermostat: There are 7 units on one programmable wall mounted thermostat and one larger unit in the back of the manufacturing area with a separate standard wall mounted thermostat.
Heating Schedule: Programming schedule is as follows: M-F; 6am-5pm set to 65 degrees F, Overnight 5pm-6am, weekends and Holidays set at 62 degrees F.
Logging Description:
The units described above were observed following the M&V plan from December 5th, 2012 until February 19th, 2013 for a total monitoring period of 75 days. One logger was set to monitor amps on the

control line or blower motor power line of the each monitored unit. Temperature loggers were also placed at the controlling thermostat 5' high, 15' high and near the ceiling at 25' high in proximity to the monitored unit. All loggers were set to record at 5 minute intervals.

The subject IR unit provided primary heat for the conditioned space of a manufacturing area where thermostat temperature set points were in the 60's. Open bay doors would increase air change rate. High firing rate and percent time on were evident in the model.

Site ID #118_IR_2 – Commercial free standing building

Tracked measures:

Quantity	Make	Model	Output Capacity
5	Space-Ray	ETU 110-30 16' Double	**110 MBTU**

Building Characteristics/Site Data:
The subject building is a commercial free standing building with office space and a large warehouse space. IR heaters are hung 22' from the floor and used to heat the warehouse space specifically when workers are using the warehouse work areas. There are six total overhead doors. Five are 10'x10' loading dock doors and not used much. One is 12'x16' and open frequently about 1-2 hours total per day area space in the warehouse. Space monitored was in a part of the warehouse used as a work area.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
16,000 sq. ft.	26'	Double cinderblock with foam cores/R-10	Rubberized roof with Fiberglass/R-11

Thermostat: Site has a total of five IR heaters installed, each with its own thermostat/switch control. Thermostats are programmable but are overridden by an on/off switch. They are set at 65 degrees and heaters switched on when workers are occupying the immediate work areas.
Heating Schedule: IR heaters are switched on/off used as needed by the facility staff.
Logging Description:
The units described above were observed following the M&V plan from December 9th, 2012 until February 19th, 2013 for a total monitoring period of 70 days. One logger was set to monitor amps on the control line of each monitored unit. Temperature loggers were also placed at points 5' from the floor and 12' high in proximity underneath the units. All loggers were set to record at 5 minute intervals.

Subject units appear to be turned off except for single-shift work hour schedule during which time the controlling logic is temperature set point. Raw data supports long periods with no fired operation. Modeling illustrates low percent time on and low firing rates. A furnace provides space heating for other insulated parts of the building on a continuous basis.

Site ID #134_IR_3 – Skating Arena

Tracked measures:

Quantity	Make	Model	Output Capacity
6	Space Ray	LTS 75-20	**75 MBTU**

Building Characteristics/Site Data:
The building is a skating arena for recreational purposes. Infrared heaters were installed over bleacher seating on both sides of the rink for the purpose of heating seated spectators during hockey games, family skating and other events, but not used during no-spectator ice time. IR heaters are mounted approximately 15' over the seating area.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
20x30 under each heater	40'	Metal panels/No apparent R-Value	Metal panels/No apparent R-Value

Thermostat: Heaters are controlled by an on/off switch in the rink office.
Heating Schedule: Schedule is based on rink functions attended by spectators. The rink is fully operational from Oct 1st-March 31st. M-F; 3pm-10pm with varying sessions. Sat-Sun; 8am-12am with varying sessions. The rink has occasional use during the off-season.
Logging Description:
The units described above were observed following the M&V plan from December 10th, 2012 until March 1st, 2013 for a total monitoring period of 79 days. One logger was set to monitor amps on the designated circuit for each set of three monitored units. There was nowhere to place temperature loggers where they could measure the temp provided by the IR heaters without high risk of them being tampered with.

Primary space heating is done by large boilers for the whole building. RTU's, unit heaters and additional hot air furnaces provide specific space heating tasks for locker rooms, bathrooms, lobby area and the spectator area. The IR utilization is based on manual override which occurs only during high occupancy events. Raw data suggests irregular usage.

Site ID #145_IR_1 – Commercial car dealership and service garage

Tracked measures:

Quantity	Make	Model	Output Capacity
3	Detroit Radiant Products	Re-Verber-Ray	75 MBTU

Building Characteristics/Site Data:
The subject building is a large commercial car dealership and service garage. The Infrared heaters were installed in the body shop space of the dealership and are mounted out at angle 16' off the floor along the back wall of the shop. There are (8) 10'x10' overhead doors to access the service bays. It was suggested that the combination of doors are opened 8-10 times a day for 10 minutes each time to move cars in and out.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
2,750 sq. ft.	18'	Block construction/No R-Value	Steel roof/No R-Value

Thermostat: Standard wall mounted thermostats on each end of the garage control heater units.
Heating Schedule: Normal temperature setting is as follows: M-F; 8am-5pm set at 45 degrees F, Nights, Weekends and Holidays set at 35 degrees F. It was mentioned by body shop staff that temperature may be adjusted accordingly if painting in the painting bays or applying various other materials that require higher temperature to work with.

Logging Description:
The units described above were observed following the M&V plan from December 7th, 2012 until February 27th, 2013 for a total monitoring period of 81 days. One logger was set to monitor amps on the control line of each monitored unit. Temperature loggers were also placed at the controlling thermostats, and points 6' from the floor, 12' high and near ceiling at 15' high in proximity underneath the heating units. All loggers were set to record at 5 minute intervals.

The subject IR units utilization in the auto body shop appears to be pre-heating of cars prior to going into the "spray booth" which is more of a process application rather than space heating application. Other equipment provides marginal heating of the non-insulated service area of the building. Entirely different heating equipment is used for the insulated portions of the building such as offices and showroom.

Site ID #213_IR_1 – Commercial free standing building

Tracked measures:

Quantity	Make	Model	Output Capacity
4	Roberts-Gordon	CTH2-125	**125 MTBU**

Building Characteristics/Site Data:
The subject building is a commercial free standing building that is combination office space and work shop/warehouse space. Two IR heated are hung 20' high in the main warehouse. An additional IR heated is located in a separate space off the warehouse used as a work shop area, the heater here is hung approximately 16' off the ground. The main warehouse has one 18'x12' overhead door used to load/unload work trucks and for deliveries. This door stays open for extended periods of time for these and other purposes.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
10,440 sq. ft.	24' Warehouse/ 20' Workshop	Block construction walls, R-6 estimate	Metal flat roof-no apparent insulation

Thermostat: Programmable thermostats are wall mounted, but are overridden manually when heat is desired.
Heating Schedule: Workers adjust as needed during 6am-4pm occupancy time period. Programming schedule sets-back to 45 degrees F at all other times.
Logging Description:
The units described above were observed following the M&V plan from December 7th, 2012 until February 28th, 2013 for a total monitoring period of 81 days. One logger was set to monitor amps on the blower motor power line of the each monitored unit. Temperature loggers were also placed at the controlling thermostats, and points 5' from the floor, 12' high and near ceiling height of 20' in proximity underneath the units. All loggers were set to record at 5 minute intervals.

IR units are utilized for warehouse area only. Other equipment provides primary heating for other areas of the building. Conditioned space temperatures in the 40's during monitoring period. Manual on/off control is being used based on work shift schedule since the warehouse area is non-insulated.

Site ID #131_IR_2 – Small commercial free standing building

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Solartronics	Suntube GQG 20' Long	**60 MBTU**

Building Characteristics/Site Data:
The subject building is a small commercial free-standing masonry building comprised of an office area that is 100 square foot (20 % of the total area of building). The rest of the building is a larger open area that serves as workshop, warehouse and equipment storage for a mechanical contractor and construction company. A loft area exists above the 10 foot ceiling offices and is continuous with the open space of the workshop area. A hot air furnace of some type provides space heating to the office area but also provides some heating to the workshop area. Details of this equipment are not known as evaluators did not have access to the office area. IR heaters were installed to provide heat to the open workshop area of the building. Two heaters are hung in the center of the building, 21' from the floor. The workshop has two 10'x10' overhead door which is opened 25 – 30 times a week for contractor access.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
5,000 sq. ft.	25'	Insulated concrete block R-5	Metal roof, rubberized exterior

Thermostat: The workshop area has standard programmable thermostat which is separate from HVAC controls for the office area of the building.
Heating Schedule: Thermostats are kept at 65 degrees F M-F 7am – 5pm, Nights, weekends, holidays at 60 degrees F. .
Logging Description:
The units described above were observed following the M&V plan from December 8th, 2012 until February 19th, 2013 for a total monitoring period of 73 days. One logger was set to monitor amps on the control line of the monitored unit. Temperature loggers were also placed at the controlling thermostat and at 5', 10' and 15' heights in the workshop area. All loggers were set to record at 5 minute intervals.

Site ID #230_IR_1 – Very large servicing garage

Building Description/Usage: Very large servicing garage capable of servicing 5-6 various size box trucks at a time. Two drive in/drive out service bays with 14'x18' overhead doors at each end. Total building floor space= 16,500 sq. ft. Ceiling is 20'-23' at peak. Walls are metal panel with R-8 insulation blankets. Roof is metal with R-8 insulation in place. Building dimensions are 150'x110'.
Tracked measures:

Quantity	Make	Model	Output Capacity
12	Detroit Radiant Products	Re-Verber-Ray	**150 MBTU**

Building Characteristics/Site Data:
Subject buildings is a complex of a large commercial free-standing building comprised of a front section with a sales floor, offices, and a small parts warehouse and three large interconnected service garages in the rear. IR heaters were installed to provide heat to sections of a these service garage. Seven heaters are hung in each building, 15' from the floor.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
16,500 sq. ft.	21’	5’ of Block then metal panels with R-8 insulation	Roof is a flat metal roof with no insulation apparent

Thermostat: A total of 4 thermostats control these IR heaters. None are programmable so are maintained at a set point temperature.

Heating Schedule/Variables: Each service bay has two extra-long (40’-50’) IR heaters. There are an additional 3 in the other service areas for a total of seven.

Other gas at site: There is a furnace for primary heating of the main building and break room areas, within the building and a 40gal DHW stand-alone for hot water.

Site ID #233_IR_1 – Commercial free standing building

Tracked measures:

Quantity	Make	Model	Output Capacity
2	Solaronics	MTS 100/65N30	**100 MBTU**

Building Characteristics/Site Data:
The subject building is a commercial free standing building comprised of both an office, receptionist space and a workshop area behind. IR heaters were installed in the work shop area approximately 11’ off the ground. Building is an older building with no apparent insulation value.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
2,625 sq. ft.	12’	Cider block/No Insulation	Flat roof/No Insulation

Thermostat: A programmable thermostat is wall mounted, but customer sets temperature each day as needed.
Heating Schedule: Night and weekend set-back is set to 55 degrees F. M-F day setting vary as needed up to 65 degrees F.
Logging Description:
The units described above were observed following the M&V plan from December 7th, 2012 until February 22nd, 2013 for a total monitoring period of 75 days. One logger was set to monitor amps on the blower motor power line of the each monitored unit. Temperature loggers were also placed at the controlling thermostat, and points 5’ from the floor and 11’ high and near the ceiling in proximity underneath the units. All loggers were set to record at 5 minute intervals.

IR Heater units installed as alternate to a boiler providing hot air heating that was not practical for the non-insulated workshop area. Heating seems to occur only during working hours because the workshop area is non-insulated.

D. Indirect Water Heaters

D.1 Indirect Water Heaters Measure Description

Indirect water heaters use an insulated storage tank containing a heat exchanger energized by a closed recirculation loop off the space heating boiler. This system design can contribute to reduced standby heat loss, increased efficiency from burner operation at or near steady-state efficiency and reduce cycling losses during the heating season.

Indirect water heating accounts for 167 projects with a total of 65,360 therms of savings in the Prescriptive Gas Tracking Data. Measurement and verification analyses were performed on 11 of these projects. These 11 projects have total annual savings of 1089.7 therms. This is 1.67% of the total tracking savings for this measure.

The 2012 version of the TRM assigns a fixed quantity of prescriptive savings of 20.7 MMBtu. Both the 2010 and 2011 versions of the TRM assign a fixed quantity of prescriptive savings, 30.4 annual MMBtu to each unit installed.

D.2 Indirect Water Heater Methodology

Onset Hobo Micro station time-of-use loggers were installed that measured the temperature of the hot water supply and return and the current to the circulating pump motor which provided the heat input to the water heater from the associated boiler. In some cases, loggers were also installed on the boiler combustion blower. The loggers were in place for between 55 and 92 days, with an average monitoring period of 76 days. The temperature at the hot water tap and/or the set point of the indirect water heater was recorded in instances where it was available. Specifications associated with the hot water circulating pump such as horsepower, flow rate and head pressure was recorded.

After logger retrieval, the data was checked for consistency and completeness. The following steps were applied to the data for each measure:

1. Loggers record pre- and post-installation data that does not represent actual operating conditions. This data was removed from the set.

2. The data set was examined for anomalies, such as readings outside the expected range. For example, the current draw by the circulating pump was recorded in a small number of 5-minute intervals during the start-up phase. In these cases, which occurred for less than a fraction of one percent of the readings, the recorded data point exceeds the average by a factor of approximately five. Since this was an instantaneous reading, and not representative of the 5-minute interval,

using this data point in subsequent analyses would skew the results. Consequently, these data points were replaced with the average of the data set absent the outliers.

The other data set required for the analysis was the typical meteorological year data for weather stations in Massachusetts, at Boston, Worcester, Millis, and Andover. This process resulted in clean and consistent sets of measured data incorporating the variables shown in Table 37 below.

Spot measurements utilizing an ultrasonic flow meter done at both the time of the installation and retrieval of the data loggers were done to identify the hot water supply and return rate of flow. There was greater success measuring flow rates associated with the indirect hot water heater sites than was found at the condensing boiler sites. The required minimum length of straight pipe of between five to twenty pipe diameters existed more often than with condensing boiler piping configurations. Furthermore, flow meter calibration was less difficult for indirect water heaters than for boilers since the indirect hot water heater hydronic loop was often stable extended periods of time even through the winter season. In the few instances where direct measurement was not possible, flow rate information calculated from the circulating pump, water heater and associated piping information. The flow rate was used in the analysis for each site

Table 37: Indirect Water Heater Variables

Variables (Study Period)		
Name	Measurement /Input Interval	Source
Hot Water Circulating Pump Motor Current (amperage)	1 or 5-minute	Data logger
Hot Water Supply Temperature at Hot Water Heater (^{0} F)	5-minute	Data logger
Hot Water Return Temperature at Hot Water Heater (^{0} F)	5-minute	Data logger
Hot Water Flow Measurement (GPM)	Spot measurement at installation and retrieval	Ultrasonic
Study Period Outdoor Dry Bulb Air Temperature (^{0} F)	Hourly	NOAA
Typical Meteorological Year Outdoor Dry Bulb Temp. (^{0} F)	Hourly	TMY

Analysis Process Steps

In this section, a high-level overview of the steps in the analysis is provided. The analysis calculates an hourly efficiency for each subject unit and uses this calculated hourly efficiency to identify the hourly difference of fuel input between the baseline case and the subject unit. The calculated hourly gas savings is summed to yield a calculated annual savings with respect to the baseline assumption of a non-condensing boiler.

Step 1. A SAS® statistical model was built to calculate hourly average values for the circulating pump current draw, the supply and return temperatures, the difference between supply and return temperatures, the percent time on and the hourly firing rates are established from the raw data from the data loggers.

Step 2. Calculated values for the average hourly Btu input to the tank are represented by the product of hourly firing rate, percent time on, flow rate of the heating water, difference in temperature of supply and return water times a constant based upon the units used.

Step 3. The hourly data set is differentiated into two periods, weekdays (WD) and weekend/holiday (WEH) to accommodate typical control strategies.

Step 4. The SAS® statistical model applies regression analysis for the time series established by the hourly operating parameters to model the relationships between hourly Btu input to the tank and hourly supply-return temperature difference to the hour of the day. Similarly, the relationship between the hour of the year and the outside temperature is modeled in parallel. This is done independently for the weekday and weekend/holiday data sets.

Step 5. The model expands the time period during the monitoring period to the full year (8760 hours) and develops the factors necessary to calculate the usage difference between the installed and baseline equipment. Hourly operating profiles for each hour of the year are developed that include the Btu input to the indirect water heater, the supply-return temperature differentiated by weekday and weekend/holiday that provides the best fit to observed measurements across the sampling period.

Step 6. Boiler efficiency, necessary to determine the boiler gas input that produces the required Btu output, is acquired from either analysis of boiler performance where monitoring devices were installed on this equipment, or from average performance data for condensing boilers operating at 88.6% combustion efficiency or higher depending upon the return water temperature.

Step 7. The baseline gas input necessary to meet the calculated demand for hot water is calculated based on the same firing rate, percent time on and pump run time fraction for a baseline hot water boiler operating at 78.0% recovery efficiency. Additionally, separate standby loss values for each of the subject and baseline units for each site are used to calculate hourly savings. The standby loss values for the baseline storage type water heater units are greater than the indirect water heater units. The AHRA product certification data clearinghouse was used as the reference for the individual standby loss values which were specific to the size and type of the units at each site. Figure 22 and Figure 23 illustrate the standby loss values of direct fired hot water heaters and indirect hot water heaters as a function of storage tank capacity respectively.

Figure 22: Direct-Fired Heaters Standby Loss

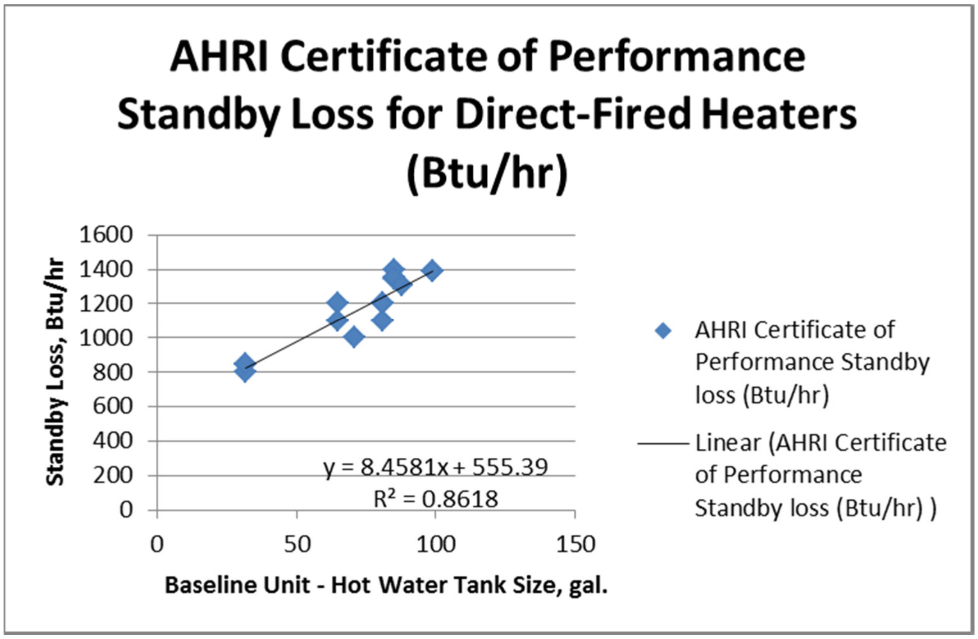
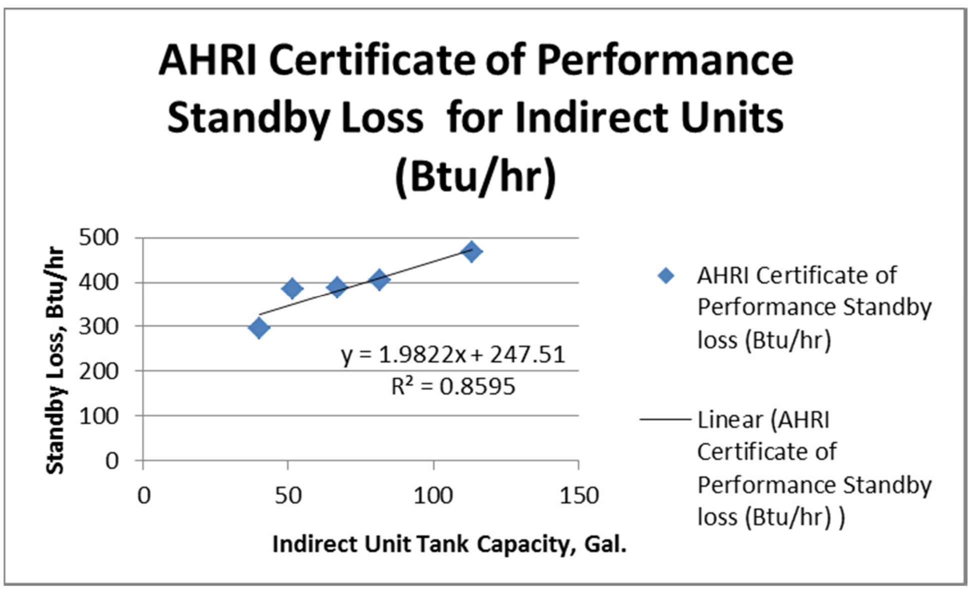


Figure 23: Indirect Heater Standby Loss



Step 8. The calculated boiler gas input and baseline boiler gas input each are summed to develop the respective annual inputs. The difference between the two is ΔMMBtu, or the evaluated savings.

D.3 Indirect Water Heater Site Description Summary

This section contains a brief overview of the sites included in the sample that had sufficient data to be carried forward into analysis.

Site ID #104_WH_3 – Condominium Units

Tracked measures:

Quantity	Make	Model	Gallons
1	Lochinvar Squire	SIT 080	82 gal

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity Input	Make	Model	Output Capacity
1	Lochinvar Knight	KBN 501	**399MBTU**

Building Characteristics/Site Data:
The subject building is an old Victorian Era triple-decker recently converted into condominium units. There are seven units total in the building. Four units are single bedroom units and three units are two bedroom units. The building is served by one commercial grade boiler which supplies heat to the building and heated water to the indirect hot water heater.

Logging Description:
The units described above were observed following the M&V plan from December 20th, 2012 until March 1st, 2013 for a total monitoring period of 70 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #152_WH_2 –

Tracked measures:

Quantity	Make	Model	Gallons
1	Smart Triple Triangle	Smart 120	119

Boiler Description:
Quantity of Input refers to the number of interconnected boilers, if more than one, supplying heated water to the indirect water heater.

Quantity Input	Make	Model	Output Capacity
1	Triangle Tube	KS399	**386 MBTU**

Logging Description:

The unit described above was observed following the M&V plan from December 12th, 2012 until March 1st, 2013 for a total monitoring period of 78 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #160_WH_1 –

Tracked measures:

Quantity	Make	Model	Gallons
1	Turbomax	65A	65

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity Input	Make	Model	Output Capacity
1	Veisman	Vitodens	200 MBTU

The subject building includes eight residential units and two store fronts.

Logging Description:

The units described above were observed following the M&V plan from December 11th, 2012 until March 1st, 2013 for a total monitoring period of 79 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #163_WH_2 – Four story commercial office building

Tracked measures:

Quantity	Make	Model	Gallons
1	HTP Superstor	Ultra SSU-80	80

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity Input	Make	Model	Output Capacity
3	u/k	u/k	u/k

Building Characteristics/Site Data:
The subject building is a four-story commercial office building. The heating system has three staged boilers to provide heat to the building and to heat the water for the indirect hot water heater. Offices are mostly associated with financial institutions so presumably are regularly occupied on a M-F 9am-5pm schedule.

Logging Description:

The unit described above was observed following the M&V plan from January 11th, 2013 until March 5th, 2013 for a total monitoring period of 52 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #166_WH_3 – Residence Hall

Tracked measures:

Quantity	Make	Model	Gallons
2	Buderus	SST 450-119	113.4

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity Input	Make	Model	Output Capacity
1	Buderus	Logamax Plus GB 162	298 MBTU

Building Characteristics/Site Data:
The building is part of a residence hall complex with an estimation of an average of 50 residents. There is a two boiler system which provides heat to the building. A third dedicated boiler heats the water for the indirect hot water heaters.

Logging Description:

The units described above were observed following the M&V plan from December 10th, 2012 until March 8th, 2013 for a total monitoring period of 87 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tanks. Both loggers recorded at a five minute interval.

Site ID #195_WH_1 – Four room cape residence

Tracked measures:

Quantity	Make	Model	Gallons
1	HTP Superstor	Ultra-SSU-45	45

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity Input	Make	Model	Output Capacity
1	Weil-McLain	Gold GV-6	153 MBTU

Building Characteristics/Site Data:

The building is a four room cape residence, which sits on the property near the visitor center and is occupied by sanctuary caretakers. Generally, there are only 1-2 occupants year round but the house can fill up with volunteer workers on some occasions.

Logging Description:

The units described above were observed following the M&V plan from December 3rd, 2012 until March 4th, 2013 for a total monitoring period of 90 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #201-WH_4D – Complex of five buildings

Tracked measures:

Quantity	Make	Model	Gallons
1	Weil-McLain	Ultra Plus 80	80

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity	Make	Model	Output Capacity
1	Weil-McLain	Ultra 155	139 MBTU

Building Characteristics/Site Data:

The subject site is a complex of five buildings, associated with house of worship organization, which serve as temporary housing units for bible camps, charity workers, students, as a shelter and for other purposes. Building D when used for bible camps during the summer may have as many as 75-80 occupants, during the rest of the year it may have only 15-20 occupants.

Logging Description:

The units described above were observed following the M&V plan from December 10th, 2012 until March 6th, 2013 for a total monitoring period of 85 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #201_WH_4E – Complex of five buildings

Tracked measures:

Quantity	Make	Model	Gallons
1	Weil-McLain	Ultra Plus 80	80

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity	Make	Model	Output Capacity
1	Weil-McLain	Ultra 155	139 MBTU

Building Characteristics/Site Data:

As above. Building E when used for camps during the summer may have as many as 75-80 occupants, during the rest of the year it may have only 15-20 occupants.

Logging Description:

The units described above were observed following the M&V plan from December 10th, 2012 until March 6th, 2013 for a total monitoring period of 85 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID # 237_WH_1 – Women's shelter

Tracked measures:

Quantity	Make	Model	Gallons
1	HTP Superstor	SSU-60	60 gal

Boiler Description:

Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity Input	Make	Model	Output Capacity
1	Not determined	Not determined	**Not determined**

Building Characteristics/Site Data:

The subject building is an old Victorian Era structure renovated and converted into a women's shelter. Typical occupancy ranged from 15-20 women, sometimes with their children, for an undetermined length of stay. One boiler system served the first and some of the second floor and provided both heat and heated water for the indirect hot water heater. A second smaller boiler system provided heat to the rest of the second floor and some third floor living space.

Logging Description:

The unit described above was observed following the M&V plan from January 11th, 2012 until March 6th, 2013 for a total monitoring period of 53 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #244_WH_4 – Free standing building

Tracked measures:

Quantity	Make	Model	Gallons
1	Triangle Tube	Smart-50	50 gal

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity	Make	Model	Output Capacity
1	KBN-800	Lochinvar	752 MBTU

Building Characteristics/Site Data:
The subject site is a three-story free standing building comprised of six small one-bedroom apartments. The original building construction is old, but has been recently renovated both inside and out. One heating system provides heat to the individual units and heats the water for the indirect hot water heater.
Logging Description:

The unit described above was observed following the M&V plan from December 6th, 2012 until March 5th, 2013 for a total monitoring period of 88 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #244_WH_4 – Large three-story multifamily housing building

Tracked measures:

Quantity	Make	Model	Gallons
2	Triangle Tube	Smart 120	119 gal

Boiler Description:
Quantity of Input refers to the number of interconnected boilers supplying heated water to the indirect water heater.

Quantity	Make	Model	Output Capacity
2	Lochinvar	KBN-800	752 MBTU

Building Characteristics/Site Data:
The subject site is a large three-story multifamily housing building which is interconnected on either end by similar large multifamily family buildings. In all these buildings comprise a large subsidized housing renovation project; completed in 2010. There are 31 units in the building of varying sizes. The building heating system is a three stage boiler set-up which provides heat to the building and hot water to two 120 gallon indirect hot water heaters.
Logging Description:

The units described above were observed following the M&V plan from December 6th, 2012 until March 5th, 2013 for a total monitoring period of 88 days. One logger was connected to the water circulation pump of the indirect water heater to monitor amps, a second logger monitored supply and return water temperatures by placing thermistors on the supply and return water pipes near the tank. Both loggers recorded at a five minute interval.

Site ID #259_WH_4B – Subsidized housing complex

Tracked measures:

Quantity	Make	Model	Output Capacity
2	HTP- Munchkin	T80M R2	74 MBTU

Building Characteristics/Site Data:
The subject buildings are a subsidized housing complex operated by a housing authority. The new condensing boilers are installed in a community center building located at the front of the complex. The building is a free standing one-story building that is brick faced with finished interior walls. This building is primarily used for special functions and is not set up as a lounge or place for residents to utilize at their own discretion. There is, however, a limited number of washing machines and dryers in the building presumably to serve just the surrounding residential units. The two boiler system provides heat to the building and circulates heated water through an indirect hot water heater.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
1,380 sq. ft.	9’	Brick faced 2x6 Wood framed/R-19	Attic with pitched roof/R-30

Thermostat: A standard wall mounted thermostat controls the two boiler system.
Heating Schedule: Building maintenance workers will turn the thermostat down to 60 degrees F whenever the building is not in use. Set-point temperature may vary depending on the utilization of the building for any particular function.

Logging Description:

The units described above were observed following the M&V plan from December 19th, 2012 until January 30th, 2013 for a total monitoring period of 41 days (Note: Loggers were removed early at the customer’s request prior to a HUD building inspection). Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #259_WH_4B – Subsidized housing complex

Tracked measures:

Quantity	Make	Model	Output Capacity
2	HTP- Munchkin	T80M R2	74 MBTU

Building Characteristics/Site Data:
The subject buildings are a subsidized housing complex operated by a housing authority. The new condensing boilers are installed in a community center building located at the front of the complex. The

building is a free standing one-story building that is brick faced with finished interior walls. This building is primarily used for special functions and is not set up as a lounge or place for residents to utilize at their own discretion. There is, however, a limited number of washing machines and dryers in the building presumably to serve just the surrounding residential units. The two boiler system provides heat to the building and circulates heated water through an indirect hot water heater.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
1,380 sq. ft.	9'	Brick faced 2x6 Wood framed/R-19	Attic with pitched roof/R-30

Thermostat: A standard wall mounted thermostat controls the two boiler system.
Heating Schedule: Building maintenance workers will turn the thermostat down to 60 degrees F whenever the building is not in use. Set-point temperature may vary depending on the utilization of the building for any particular function.

Logging Description:

The units described above were observed following the M&V plan from December 19th, 2012 until January 30th, 2013 for a total monitoring period of 41 days (Note: Loggers were removed early at the customer's request prior to a HUD building inspection). Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.

Site ID #259_WH_4R – Subsidized housing complex

Tracked measures:

Quantity	Make	Model	Output Capacity
2	HTP- Munchkin	T80M R2	74 MBTU

Building Characteristics/Site Data:
The subject buildings are a subsidized housing complex operated by a housing authority. The new condensing boilers are installed in a 6-unit multifamily building (Building 9-11) that is typical to the complex. The building is a free standing two-story building that is brick faced with finished interior walls. Heating and hot water use would be typical of residential multifamily housing. The two boiler system provides heat to the building and circulates heated water through an indirect hot water heater.

Area of heated space	Ceiling Height	Wall Construction/R-Value	Roof Construction/R-Value
3,900 sq. ft.	8'	Brick faced 2x6 Wood framed/R-19	Attic with pitched roof/R-30

Thermostat: The system is zoned for individual thermostats in each unit.
Heating Schedule: Overall building heat is a combination of individualized set-point adjustments by tenants in each unit.

Logging Description:

The units described above were observed following the M&V plan from December 19, 2012 until January 30, 2013 for a total monitoring period of 41 days (Note: Loggers were removed early at the customer's request prior to a HUD building inspection). Each boiler was monitored with a logger set to record combustion blower amps, circulator pump amps, and supply and return water temperatures at five minute intervals.